THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

ART. I.—*On the Inequalities in the Moon's Motion produced by the Oblateness of the Earth;* by Professor J. N. STOCKWELL.

HAVING given in the November number of this Journal, an account of a secular inequality in the moon's motion, arising from the oblateness of the earth, I propose to give, in the present number, a somewhat detailed account of the principal periodic inequalities in the motions of the moon arising from the same cause. And I would here state that a careful study of the effect of the earth's ellipticity on the motions of the moon, through the medium of analysis, has presented some of the most curious and interesting cases of perturbation to be found in physical astronomy. The principal inequalities to which I would call attention, are chiefly remarkable as being the product of a number of important, though mutually antagonistic forces, the resultant of which, on any given coördinate of the moon, is of far less importance than would arise from the undisturbed operation of any one of the constituent forces; and I do not remember any cases of perturbation in the moon's motion, arising from the sun's attraction, in which the effect of the force on any given coördinate is so completely neutralized by the action of the same force on some of the other elements of motion. The analysis which I have employed has presented the results in such shape as to show: *First*, the separate effect of the earth's oblateness on the motions of the moon; and *Second*, the combined effect resulting from the earth's figure and the sun's attraction. It is from these two points of view that I shall now consider the subject.

In the paper referred to above, it was shown that the motion of a body moving in a circular orbit in the plane of the equator would be uniform; and that the motion in a circular orbit which was inclined to the equator would be subject to inequalities, the magnitude of which would depend on the inclination of the orbit to the equator. Now the ecliptic is inclined to the equator at an angle of 23° 27′, and the moon's orbit is inclined to the ecliptic at an angle of 5° 8′. If, then, the ascending node of the moon's orbit is at the vernal equinox, the inclination of the moon's orbit to the equator will be 28° 35′; and she will attain to that degree of declination twice during each sidereal revolution. In this position of the node, the inequalities of the earth's attraction on the moon attain their maximum values. Suppose, now, that the ascending node is at the autumnal equinox. It is evident that the inclination of the orbit to the equator will be only 18° 19′, and that she will only reach that declination twice during each revolution. The inequalities of the earth's attraction on the moon, in this last position of the node, will evidently be at their minimum values. As the node passes from one equinox to the other, it is plain that the inequalities of the earth's attraction on the moon pass through all the changes of value to which they are at any time subject. Now the moon's node makes a complete revolution on the ecliptic in a period of 18·6 years; consequently all the inequalities of the moon's motion arising from the oblateness of the earth will effect a complete restoration in that period. Since the motion of the moon's node is caused by the sun's attraction, we must, in the calculation of the separate effect of the spheroidal form of the earth on the moon's motion, neglect the sun's attraction and regard the elements of the moon's orbit as constant, except so far as they are affected by the form of the earth itself. From these general considerations it follows that the moon's declination, on which the inequalities of the earth's attractive force depends, is affected by two conditions: namely, the longitude of the moon and the longitude of the node. I shall therefore in the present paper consider only the inequalities which depend on these two elements, either separately or in combination.

In the calculations which I have made, the oblateness of the earth has been taken as $\frac{1}{300}$; and in the few equations which are given, the symbols have the following significations: a and nt denote the moon's mean distance and mean longitude; v and θ denote the moon's true longitude and latitude. γ and Ω denote the inclination and longitude of node of moon's orbit; ϵ denotes the obliquity of the ecliptic, and D denotes the mean radius of the earth; ρ and φ denote the oblateness of the earth, and the ratio of the centrifugal force to the gravity at

the earth's equator; R denotes the disturbing function; and δ placed before a quantity denotes the variation of that quantity arising from the oblateness of the earth. I also put for brevity

$$\beta = \{\rho - \tfrac{1}{2}\varphi\}\frac{D^2}{a^2}\sin\varepsilon\cos\varepsilon. \qquad (1)$$

I now give the equations which express the variations of the elements and coördinates of the moon, and which are independent of the sun's action. In the first place I find that the position of the node and inclination of the orbit are affected by the following inequalities:

$$\delta\Omega = \tfrac{1}{2}\frac{\beta}{\gamma}\sin(2nt - \Omega) = +\,0''\cdot185\sin(2nt - \Omega), \qquad (2)$$

$$\delta\gamma = \tfrac{1}{2}\beta\cos(2nt - \Omega) = +\,0''\cdot0165\cos(2nt - \Omega). \qquad (3)$$

These two inequalities give rise to the following inequality in the moon's latitude:

$$\delta\theta = -\tfrac{1}{2}\beta\sin nt = -\,0''\cdot0165\sin nt. \qquad (4)$$

But I find that the direct action of the earth on the moon produces the following inequality:

$$\delta\theta = +\tfrac{1}{2}\beta\sin nt, \qquad (5)$$

The sum of these two inequalities gives $\delta\theta = 0$; whence it follows that there is no equation of the above form in the moon's latitude arising from the oblateness of the earth. In other words, the figure of the earth does not cause the moon to depart from the plane of the great circle in which its orbit is situated.

The above values of $\delta\Omega$ and $\delta\gamma$ also give the following inequality in the moon's longitude:

$$\delta v = +\tfrac{1}{4}\beta\gamma\sin\Omega = +\,0''\cdot00074\sin\Omega). \qquad (6)$$

The direct action of the earth on the moon produces the following inequalities in the longitude:

$$\left.\begin{aligned}\delta v &= \tfrac{1}{12}\beta\tan\varepsilon\sin 2nt - \tfrac{1}{12}\beta\gamma\sin(2nt - \Omega)\\ &= +\,0''\cdot0012\sin 2nt - 0''\cdot00025\sin(2nt - \Omega).\end{aligned}\right\} \qquad (7)$$

These inequalities in longitude are so excessively small as to be entirely insensible. The sum of the coefficients in these three terms of δv amounts to only $0''\cdot0022$, a quantity not exceeding *fourteen feet* if measured on the moon's orbit. From this calculation it follows that, if the moon were entirely free from solar disturbance, the effect of the oblateness of the earth on its motions would be so small that it would never be detected by observation.

Let us now examine into the effect of a combination of solar disturbance with that arising from the earth's oblateness. Since we have supposed the moon's orbit to be circular, it is

evident that the earth's attraction on the moon is at a maximum whenever the moon is in the equator, or twice during each revolution of the moon. We will now suppose that the longitude of the moon's node is 90°, and examine into the consequences that must take place while it retrogrades through a semi-circumference, or from +90° to −90°.

When $\Omega = +90°$, the moon's orbit intersects the equator at a distance of 12° 45′ to the eastward of the equinox: and since the node retrogrades on the ecliptic about 1° 27′ during a sidereal revolution of the moon, it follows that the moon will arrive at the equator at a point a little to the westward of its previous crossing. In other words, the moon will make a complete revolution with respect to the center of force in a period somewhat shorter than the sidereal revolution. At the end of 9·8 years the longitude of the node will be −90°, and the orbit will intersect the equator at a distance of 12° 45′ to the westward of the equinox. Now the moon performs 124·3256 sidereal revolutions while the node is retrograding through an arc of 180°. But 124·3256 sidereal revolutions correspond to 124·3256 revolutions +23° 21′ with respect to the equator. Whence it appears that while the node is retrograding from +90° to −90°, the time of revolution with respect to the equator is shorter on an average by $20^m\ 32^s$ than the sidereal revolution. It is plain that while the node is retrograding from −90° through the autumnal equinox to +90°, the point of intersection of the orbit and equator will advance from −12° 45′ to +12° 45′, and the time of revolution of the moon with respect to the equator will exceed the time of the sidereal revolution by the same amount that it fell short of that quantity while retrograding through the other half of the orbit. It is also plain that the inclination of the orbit to the equator increases while the equatorial node is approaching the vernal equinox, at which point it is a maximum, and diminishing while it is receding from it. The constant retrograde motion of the ecliptic node of the moon's orbit, therefore, gives rise to a merely oscillatory motion of the equatorial node; and it is this pendulum-like motion of the equatorial node that gives rise to a number of inequalities in the moon's motion which I now proceed to consider; observing that the inequalities which are produced while the node is advancing are fully compensated by means of the retrograde motion which follows.

I now give the values of the perturbations of the elements and coördinates which I have obtained, as resulting from the motion of the moon's node, which is produced by the sun's attraction. I find

$$\left.\begin{aligned} \delta\Omega &= -\frac{\beta}{\alpha\gamma}\sin\Omega = +91''\cdot324\sin\Omega \\ \delta\gamma &= +\frac{\beta}{\alpha}\cos\Omega = -8''\cdot2233\cos\Omega \end{aligned}\right\}; \tag{8}$$

a being the ratio of the motion of the node to the moon's mean motion. These inequalities of the elements give rise to the following inequality in the latitude:

$$\delta\theta = \frac{\beta}{\alpha}\sin nt = -8''\cdot2233\sin nt. \tag{9}$$

This is exactly the same as LaPlace and subsequent investigators would have obtained had they used the same value of the earth's ellipticity. This inequality in the moon's latitude is equivalent to the supposition that the moon's orbit, instead of moving on the plane of the ecliptic with a constant inclination, moves, with the same condition, upon a plane passing always through the equinoxes, between the ecliptic and equator and inclined to the ecliptic by an angle which is equal to $\frac{\beta}{\alpha}$, as LaPlace has remarked.

I have not, however, been equally fortunate in reproducing the value of the inequality in the moon's longitude, which LaPlace and later investigators have obtained. I find as directly resulting from the motion of the moon's node, the following inequality in the longitude:

$$\delta v = -\frac{\beta}{\alpha^2}\gamma\sin\Omega = -184''\cdot3\sin\Omega. \tag{10}$$

But the preceding inequality in latitude gives rise to the two following inequalities in the longitude:

$$\left.\begin{aligned} \delta v &= +\frac{\beta}{\alpha_2}\gamma\sin\Omega - \tfrac{1}{2}\frac{\beta}{\alpha}\gamma\sin(2nt-\Omega) \\ &= +184''\cdot3\sin\Omega + 0''\cdot37\sin(2nt-\Omega) \end{aligned}\right\}. \tag{11}$$

The first of these two inequalities derived from the perturbations in latitude exactly cancels the preceding inequality in the longitude which is produced directly from the retrograde motion of the node; and we have as the resultant of the two forces,

$$\delta v = -\tfrac{1}{2}\frac{\beta}{\alpha}\gamma\sin(2nt-\Omega) = +0''\cdot37\sin(2nt-\Omega). \tag{12}$$

I find, however, that the radius vector of the moon's orbit is affected by the inequality

$$\delta v = 3a\beta\gamma\cos\Omega, \tag{13}$$

and this produces the following inequality in the longitude,

$$\delta v = -6\frac{\beta}{\alpha}\gamma\sin\Omega = +4''\cdot443\sin\Omega, \tag{14}$$

while LaPlace found

$$\delta v = -\tfrac{1}{2}\frac{\beta}{\alpha}\gamma \sin \Omega = +7''{\cdot}03 \sin \Omega. \qquad (15)$$

If, in the development of the inequalities depending on the oblateness of the earth we carry on the approximations so as to include terms of a higher order depending on the eccentricity and inclination of the orbit, we shall find two equations of sensible magnitude, having the same arguments as two empirical equations discovered by Airy about a third of a century ago. These equations depend on the arguments $nt - \omega - \Omega$, and $nt - \omega + \Omega$, in which ω denotes the longitude of the perigee. These arguments have periods of 27·4432 days, and 27·6661 days, respectively. The equation depending on the first of these arguments seems also to have been independently discovered quite recently, as an empirical equation, by Professor Newcomb, who attributes it to the attraction of some of the planets. From some calculations which I have made I am led to suspect that each of these equations has a value amounting to quite a large fraction of a second of arc; and I call attention to them here as being worthy of a more thorough investigation by astronomers.

It is but proper to add in this connection, that the mean motions of the perigee and node of the lunar orbit are affected by the oblateness of the earth; and are also affected by secular equations arising from the diminution of the obliquity of the ecliptic. The motions of the perigee and node which I have obtained agree in value with those obtained by LaPlace. I have therefore succeeded in reproducing exactly, by my method of computation, all the inequalities in the motions of the moon arising from the oblateness of the earth, which LaPlace discovered nearly a century ago, with the exception of the equation in longitude. The coefficient of LaPlace's equation exceeds the value which I have obtained, in the ratio of 19 to 12; and it has been a matter of surprise that two very dissimilar methods of computation should give so many results identically the same, and leave only a single one discordant. This has led me to make a critical examination of every step of LaPlace's calculation of this equation; and this examination has developed the fact that LaPlace has, in this instance, departed widely from the requirements of his own formulæ and methods; and that a correct calculation by his method gives a result identically the same as I have found by my own. I shall therefore now give the several steps of this examination, believing that it will not be without interest to the readers of this Journal. In this investigation it has been found convenient to use Bowditch's translation of the *Mécanique Céleste*,

as the facilities for referring to any part of the work by means of the marginal numbers are much better than in the original. I shall also change the notation somewhat, putting ε for λ, and a for $g-1$ in some cases, and shall also put $f=1$. The numbers inclosed in brackets refer to the corresponding marginal numbers of the *Mécanique Céleste*.

The expression of the force R, [5362] becomes by using the value of β, which is given by equation (1) of this paper, and putting $f=1$,

$$R = 2\frac{a^2\beta}{r^3} s \sin v. \tag{16}$$

In this equation s denotes the tangent of the moon's latitude. This value of R gives the following values of the partial differential coefficients,

$$\left(\frac{dR}{dr}\right) = -6\frac{a^2\beta}{r^4} s \sin v, \tag{17}$$

$$\left(\frac{dR}{dv}\right) = 2\frac{a^2\beta}{r^3} s \cos v, \tag{18}$$

$$\left(\frac{dR}{ds}\right) = 2\frac{a^2\beta}{r^3} \sin v. \tag{19}$$

The equation which determines the value of δv, is [5367], namely,

$$d\delta v = 3\frac{dt^2}{r^2\,dv}\int \mathrm{d}R + 2\frac{dt^2}{r^2\,dv} r\left(\frac{dR}{dr}\right); \tag{20}$$

and the value of dR is

$$\mathrm{d}R = \left(\frac{dR}{dr}\right)dr + \left(\frac{dR}{dv}\right)dv + \left(\frac{dR}{ds}\right)ds. \tag{21}$$

The value of s is given by the equation [5376], namely,

$$s = \gamma \sin(gv - \Omega), \tag{22}$$

in which I have changed θ to Ω, in order to avoid confusion of symbols. Now (22) gives by differentiation

$$ds = g\gamma\,dv \cos(gv - \Omega). \tag{23}$$

If we neglect the eccentricity of the orbit we shall have $dr=0$, consequently the term $\left(\frac{dR}{dr}\right)dr$ will vanish from the value of $\mathrm{d}R$. Now substituting the value of s, (22) in (18), and multiplying (19) by ds, which is given by (23), we shall get,

$$\left(\frac{dR}{dv}\right)dv = a^2\frac{\beta}{r^3}\gamma\,dv\,\{\sin(gv + v - \Omega) + \sin(gv - v - \Omega)\}. \tag{24}$$

$$\left(\frac{dR}{ds}\right)ds = a^2 g\frac{\beta}{r^3}\gamma\,dv\,\{\sin(gv + v - \Omega) - \sin(gv - v - \Omega)\}. \tag{25}$$

If we substitute these values in equation (21), and retain only the term depending on the angle $(gv - v - \Omega)$, it will become

$$dR = -a^2 \frac{\beta}{r^3} \gamma (g-1)\, dv \sin (gv - v - \Omega.) \tag{26}$$

This gives by integration

$$\int dR = a^2 \frac{\beta}{r^3} \gamma \cos (gv - v - \Omega). \tag{27}$$

If we substitute the value of s in equation (17) and multiply by r it will become

$$r\left(\frac{dR}{dr}\right) = -3a^2 \frac{\beta}{r^3} \gamma \cos (gv - v - \Omega). \tag{28}$$

Substituting (27) and (28) in (20), it becomes

$$d\delta v = -3a^2 \frac{\beta}{r^3 dv} \frac{\gamma}{r^3} \cos (gv - v - \Omega). \tag{29}$$

This is the same as LaPlace has given in [5368].

But LaPlace has given a second term depending on the same argument. This second term arises from the variation of the sun's disturbing force which is due to the variation of the moon's latitude produced by the earth's oblateness. The expression of this force is given in equation [5372] and is as follows:

$$\delta R = \tfrac{3}{2} m' u'^2 r^2 s \delta s. \tag{30}$$

I shall now show that this value of δR is the same as the value of R given by equation [5362], except that it has a contrary sign.

According to [5374] we have

$$\tfrac{3}{2} m' u'^2 r^2 = \tfrac{3}{2} \frac{m^2}{r} = 2 \frac{g-1}{r}, \tag{31}$$

and if we substitute this in (30) or [5372] it becomes

$$\delta R = 2 \frac{g-1}{r} s \delta s. \tag{32}$$

And if we substitute in this, the value of δs given by [5376], which reduced to the notation of this article is

$$\delta s = -a^2 \frac{\beta}{(g-1) r^3} \sin v, \tag{33}$$

it becomes

$$\delta R = -2a^2 \frac{\beta}{r^3} \sin v. \tag{34}$$

This is the same as (16) or [5362] except that it has a contrary sign. This force is therefore the reaction of the force expended by the sun in giving motion to the moon's node, which in turn produces the inequality in the moon's latitude.

But in this second part of his work LaPlace seems to have committed a grave oversight, for he has treated his equation [5372] in the construction of [5373], as though δs were constant; whereas it is a function of both r and v, according to

[5376] which he afterwards uses in his reductions. However, as I have shown above that equation [5372] is the same as [5362], and has a contrary sign, it is unnecessary to pursue this part of the inquiry further, since it is evident that the whole value of δv must be derived from the value of R in [5362].

LaPlace has given the complete value of $d\delta v$ corresponding to the plane of the orbit, in [5379]; and he gives a correction in [5385] to reduce it to the plane of the ecliptic. It is apparent, however, that this correction does not exist, for LaPlace has shown in [923′] etc., where this subject is first investigated, that this correction is of the order of the square of the disturbing force; and as terms of that order have not been considered, it is evident that the value of that correction which he has given in [5385] is erroneous.

To complete this subject, it now remains to be shown that the value of R in equation [5362] gives the value of $d\delta v$ twice as great as LaPlace has found in [5368]. For this purpose I would remark that the value of $d\delta v$ given by means of [5367], is the correction to the *disturbed mean longitude*, and not to the undisturbed mean longitude. In order to correct for this condition it is necessary to add the term $3\frac{dt^2}{r^3 dv}\int \mathrm{d}R$ to the first member, and this cancels the same term in the second member, thus leaving the correction to the *undisturbed mean longitude*, or δv equal to

$$\int 2\,\frac{dt^2}{r^3 dv}\, r\left(\frac{dR}{dr}\right).$$

This will be apparent from the considerations given in § 54 of Book II of *Mécanique Céleste*, from which it appears that the function $\mathrm{d}R$ has a term of the form $\sin(\alpha t + \beta)$, in which α is very small, and gives by a double integration α^2 as a divisor; and LaPlace has shown in [1070′] that for this case we must increase the mean longitude by the quantity $3\frac{a}{\mu}\int ndt \int \mathrm{d}R$, which is equal to $3\int \frac{dt^2}{r^3 dv}\int \mathrm{d}R$, or to the first term of the second member of equation [5367]. It therefore follows that the complete value of $d\delta v$ will be given by the equation

$$d\delta v = 2\,\frac{dt^2}{r^3 dv}\, r\left(\frac{dR}{dr}\right). \qquad (35)$$

and if we substitute the value of $r\left(\frac{dR}{dr}\right)$ given by [5365] it becomes equal to twice equation [5368], or identically the same as I have obtained by an entirely different method.

Cleveland, Ohio, Oct. 29, 1879.

ART. II.—*An Electro-Dynamometer for Measuring Large Currents;* by WALTER N. HILL, S.B. (Harvard), Chemist, U. S. Torpedo Station, Newport, R. I.

THE use of electric machines of large size, for the generation of currents of great strength, has become extensive and promises to increase materially. In connection with this, the best mode of measuring the currents obtained is a matter of much importance, as well as one of some difficulty.

Probably at the present time, the method by the use of the galvanometer—heavily shunted—and that involving the determination of the heat developed in the circuit are the most used, but they are objectionable from their inconvenience, complexity and liability to many errors.

The method employing the electro-dynamometer is to be preferred for many reasons and it has also the advantage of being applicable to to-and-fro currents, as well as to those in one direction.

Weber's form of the electro-dynamometer is an instrument which, as Clerk-Maxwell says, "is probably the best fitted for absolute measurements." In this, one coil is suspended within another, the suspension being a fine wire through which the current is led to the suspended coil. It is therefore only suitable for the direct measurement of very small currents. If currents of greater strength are employed, the suspending wire is heated and elongated. It is consequently necessary in measuring powerful currents with Weber's electro-dynamometer to use very large shunts.

As has been pointed out by Trowbridge, it is very desirable to avoid the use of shunts, since the entire resistance of the circuit is of the same order of magnitude as the shunt. In general, a method depending upon the measurement of a *very small proportional part* of the whole current is objectionable, since very great accuracy is necessary and errors of observation are exaggerated.

Trowbridge has designed an electro-dynamometer through which large currents may be transmitted and directly measured. (Proc. Am. Acad. Arts and Sci., Oct. 9, 1878). It consists essentially of two large fixed coils made from copper bands, between which is suspended, from a torsion head, a small coil—the whole so arranged that by means of mercury connections the entire current will traverse the smaller coil, as well as the larger ones. A small mirror is attached to the deflecting coil and by means of a telescope and scale, the deflections may be read. In practice, however, Trowbridge found that the better mode of observation was to bring back, by the torsion head,

the coil to the zero point determined by the telescope, scale and mirror. This instrument gives good results. Measurements can be made more rapidly with it than by the galvanometric method and without shunting.

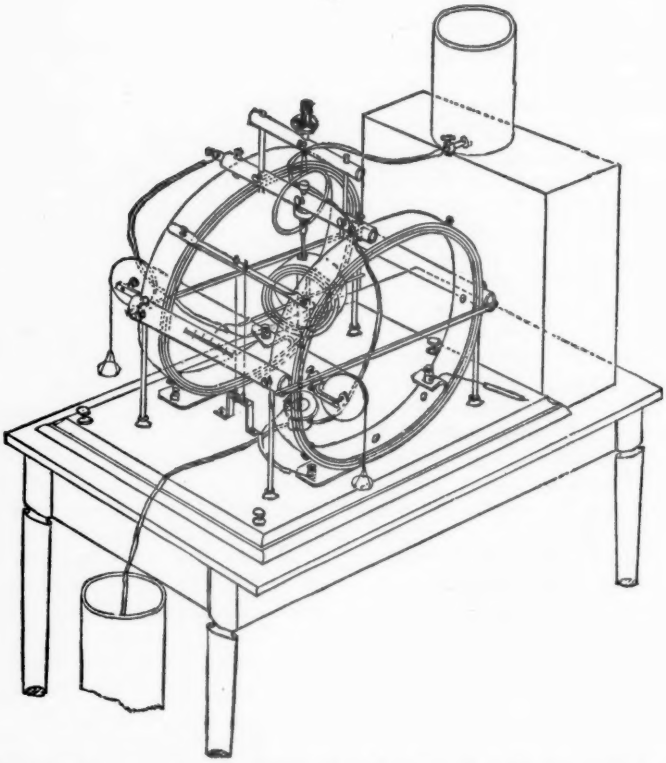
During the past year, the writer has been experimenting at the U. S. Torpedo Station with an electro-dynamometer, differing from Trowbridge's in the manner of observing or determining the deflective power of the current. In its general plan, including the arrangement for taking the entire current to be measured, it follows Trowbridge's form.

Fig. 1 is a general view of the instrument. Figs. 2 and 3 show the details of the suspended coil. The large fixed coils are made of copper ribbon 37^{mm} wide by $1\frac{1}{2}^{mm}$ thick. The turns are separated by ebonite rings and fastened together by brass rods and screw-nuts insulated by ebonite. The metal frame-work is similarly insulated from the coils. The suspension arrangement is placed on the top of the fixed coils and insulated from them. The upper cylinder which carries the suspension pulley is capable of vertical motion and can be fixed in any position by set-screws.

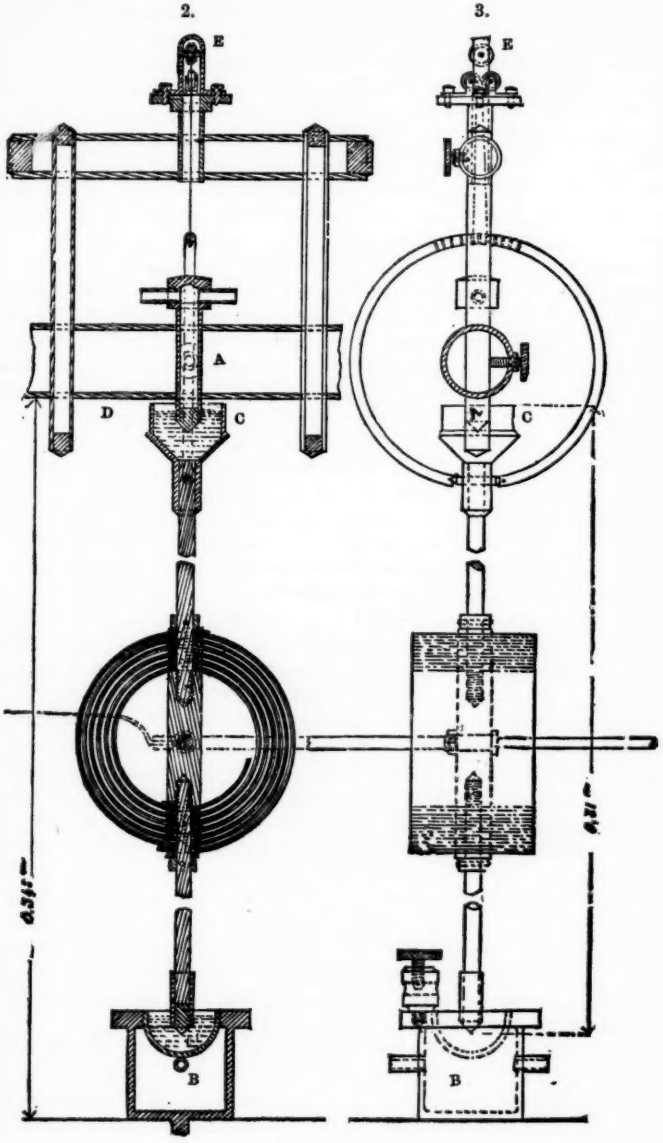
The deflecting coil (figs. 2 and 3) is made of copper ribbon 49^{mm} wide by $1\frac{1}{2}^{mm}$ thick, fastened with insulated rivets. In the center of the coil and parallel with it, is a light brass rod or pointer. A copper rod in connection with the outer end of the coil has an iron or nickel-plated point, which dips in mercury contained in a double-walled metal cup, B, on the base-board. A similar rod from the inner extremity of the coil, ends in an iron or nickel-plated cup, C, containing mercury. By means of a ring, the coil is hung directly under the metal cylinder, D, which lies centrally across the tops of the large coils. Through an opening in the center of this cylinder, passes a hollow metal plunger, A, which dips in the mercury contained in the cup of the small coil. The suspension is of fine sewing silk, waxed or shellaced. The thread passes over a little pulley, E, above, with both parts parallel or nearly parallel and close together. As represented in fig. 1, the large coils are connected "tandem." The current would enter the left hand coil at the screw-post in front; from the other end of this coil, a thick wire leads to the metal cylinder lying across the large coils, making connection with the small coil by its mercury cup, and from the mercury cup below a wire passes to one end of the other large coil. In order to prevent heating of the mercury connections, the plunger A is hollow and the cup B is double walled, so that a stream of cold water may be sent through them from the jar placed upon the stand above the instrument, the necessary connections being made by means of small rubber tubes.

When the current passes, the suspended coil is powerfully deflected but its actual movement is limited by a vertical wire stop. There are two of these stops, one on each side of the pointer-rod of the suspended coil. They are about 15^{mm} apart, so that the rod can move but 7·5^{mm} on either side the center. To the pointer-rod are attached on opposite sides, two silk threads which lead over pulleys on the side bars to small pans, one on each side of the instrument. (Fig. 1). The pulleys are

1.



62^{mm} in diam. and have scores for the threads. They are light, nicely balanced and turn on hardened steel pivots. When deflection has occurred, weights are added to the pan on the side opposite until the pointer-rod returns to the starting point. If the weight added is too great, the pointer-rod is drawn against the other wire stop. Weights may then be removed or put into the opposite pan, until the right point is attained.


2.
3.
E
E
A
D
C
C
B
B

The weight employed exactly balances the magnetic force. The mode of observing the zero point was not quite satisfactory. It was originally intended to use a vertical wire stop, the pointer-rod to be drawn back until it just touched the wire, but it was found that it was difficult to hit this point exactly. Finally, a scale was marked on the cylinder in front of the instrument (fig. 1) and a pointer of aluminum wire fastened to the rod, so that it would traverse the scale. This plan worked well and with more careful construction will doubtless be sufficient, but a better method is probably one suggested by Captain F. M. Ramsay, U. S. N., which is to use a light vertical pointer hanging over the scale on the base. When adjusted, the pointer-rod of the suspended coil should just touch the vertical pointer when the latter is at zero. The exact return to the same point would be easily seen, as a small excess of weight would cause a movement of the pointer over the scale.

The pans are of the same weight and the threads by which they are hung, are fibers of unspun silk. The friction of the pulleys is very small, and would be trifling if they were made with jewelled bearings. Also, one balances or nearly balances the other, so that practically their friction may be neglected, although allowance might be made for it if extreme nicety were aimed at. It must be remembered that the actual observation is made when the coil is in the zero position, the weight taken being that required to *balance* the deflecting force. The movement of the pulleys is then very slight and the weight acts exactly at right angles to the pointer-rod.

For the measurement of the large currents derived from dynamo-electric machines, minuteness is not demanded, since the variations due to fluctuations in the currents, alterations in resistance, etc., are much greater than the limits of observation in such an instrument as this. Thus in practice, when attempting to ascertain the current obtained per horse power expended, we have to note the velocity of the machine and the indications of the power dynamometer, together with the current measure, as nearly as possible at the same moment. Quickness and simplicity of working, together with strength and compactness are required in the electro-dynamometer, and this instrument possesses these practical advantages, while it is capable of a good degree of accuracy.

The writer has employed it at the U. S. Torpedo Station for measuring currents of from 20 to 80 webers. It is a good working instrument and gives uniform results. It was made for experimental trial and is defective in certain respects. With some improvements in construction, it would be a little more sensitive, particularly to comparatively small currents. The

suspension arrangement is supported on the large coils and lacks steadiness. It should be placed upon a distinct standard. A support for the deflecting coil when not in use, should be added and an arrangement for centering it quickly.

Theory of the Instrument.—The expression for the strength of current is very simple. The weight found is that required to balance the deflective force and is observed at zero, so that the earth's and local attractions are avoided, nor does the torsion of the suspension enter. Let

S = strength of current in webers.
w = weight used, in milligrams.
l = length of weight-arm or distance from point where weight acts, to center of system.
G = constant of large coils.
g = constant of small coil.
C = constant of instrument or length of magnetic arm.

By the theory of the electro-dynamometer, the force acting to deflect is represented by the expression $\frac{2\pi n}{r} \times g \times S^2$, in which $\frac{2\pi n}{r}$ is the constant of the large coils or G, and g the constant of deflecting coil. This force acts with the arm C, and is balanced by the weight acting with the arm l. Hence

$$S^2 = \frac{lw}{CGg}.$$

The coils being large, G and g are readily ascertained from measurement. l is a known distance. C is the constant of the instrument and must be specially determined. With the instrument in question, C was found by running the same currents through it and through Trowbridge's dynamometer, the constant of which was accurately known. C, l, G, and g being known, it is evident that from weight found, the current may be obtained with little calculation. Or, a table may be drawn up from which the values desired can be obtained by inspection.

With this instrument, which has many turns in the fixed and movable coils, the deflections are powerful, requiring weights to balance them large enough to give sufficient sensitiveness.

The following table shows the weights required for currents from 21 to 30 webers, and from 91 to 100 webers, with my instrument as arranged.

S. webers.	w. grm.	diff.	S. webers.	w. grm.	diff.	S. webers.	w. grm.	diff.	S. webers.	w. grm.	diff.
21	·58		26	·89	·70	91	10·92		96	12·15	·25
22	·64	·06	27	·96	·07	92	11·16	·24	97	12·41	·26
23	·70	·06	28	1·03	·07	93	11·40	·24	98	12·66	·25
24	·76	·06	29	1·11	·08	94	11·65	·25	99	12·92	·26
25	·82	·06	30	1·19	·08	95	11·90	·25	100	13·19	·27

This table shows whole webers only, which, for some purposes, would be sufficient, but the subdivisions can be supplied if desired. Thus, we have between 59 and 60 webers:

S. webers.	*w.* grm.	S. webers.	*w.* grm.
59·	4·590	59·6	4·680
59·1	4·605	59·7	4·700
59·2	4·620	59·8	4·715
59·3	4·635	59·9	4·730
59·4	4·650	60·	4·750
59·5	4·665		

If a set of weights arranged for ordinary balance use is employed, it would be better to draw up the table to correspond, making the difference between any two contiguous terms of w, the smallest weight taken. Thus my instrument indicates 10^{mg}, which gives sufficient minuteness.

It is plain that a set of weights could be made which would represent webers current, making any calculation unnecessary. This would be often convenient, if much work was to be done.

For technical purposes, when an approximate measure is sufficient, a set which would not be too cumbrous might have brass weights for differences of five webers, and platinum ones for intermediate figures. Thus, between 30 and 40 webers:—

Principal weights.	Minor weights.	S.
1·185 grm.	1 ·085 grm. 2 ·170 grm.	30 webers.
	1 ·085	
1·615	1 ·095	
	·095 2 ·195	35
2·110	1	40

With this instrument, I have worked with currents as small as 10 webers, but it is not sensitive enough for such use. Above 20 webers, it operates satisfactorily. Greater nicety of construction would confer greater sensitiveness to small weights, but it is evident that this form of the dynamometer is particularly suitable for *large* currents.

We have $S : S' :: \sqrt{w} : \sqrt{w'}$,

That is, as the currents increase, the corresponding weights increase more rapidly and greater accuracy and minuteness are attained. Between 21 and 22 webers, the difference of weight is ·06 grm., and between 99 and 100 ·27 grm.

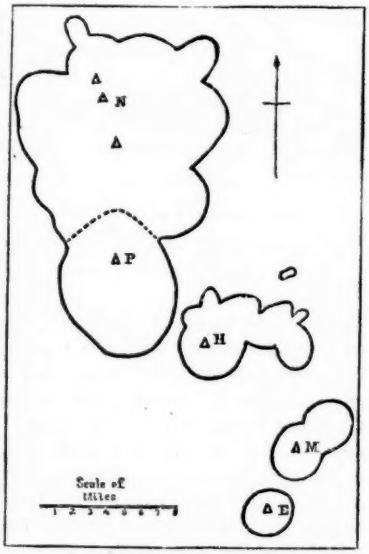
My best thanks are due to Prof. John Trowbridge, of Harvard University, for advice and the use of his apparatus.

U. S. Torpedo Station, Newport, R. I., October 25, 1879.

Art. III.—*Gilbert's Report on the Geology of the Henry Mountains.**

Mr. Gilbert presents much that is new to Geology in his account of the Henry Mountains. These mountains—so named by Mr. Powell in honor of Professor Joseph Henry—are situated in Southern Utah, about the meridian of 110° 45′, and the parallel of 38°. They are an irregular group—not a range—of five mountains, the highest about 5,000 feet above the arid plateau at their base, and 11,000 feet above the sea. It is stated that although much cut up by vallies of erosion, they still show, to some extent, by their forms, but chiefly by the dip of their beds, that they were originally mammiform bulgings of the strata of the region, or groups of such bulgings. The accompanying figure is a ground-plan of the Henry Mountains: N, Mt. Ellen; P, Mt. Pennell; H, Mt. Hillers; M, Mt. Holmes; E, Mt. Ellsworth; it represents N (Mt. Ellen), P (Mt. Pennell), H (Mt. Hillers) as each a group; M (Mt. Holmes) as a combination of two domes, and E (Mt. Ellsworth) alone as single. The single bulgings or domes vary in diameter from half a mile to four miles, and the outline is nearly circular or somewhat oval, though more or less irregular where they have encroached on one another.

1.



Map of the Henry Mountains.

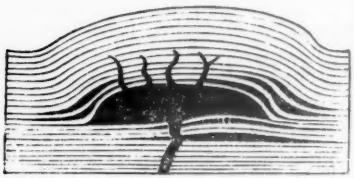
The strata constituting them are those of the Cretaceous formation, which comprises, beginning above, the "Maruk," "Blue Gate" and "Tununk" sandstones, and "Henry's Park Group," and has there a thickness of 3,500 feet; the Jura-Trias, which is divided into the "Flaming Gorge," "Gray Cliff,"

* Report on the Geology of the Henry Mountains, by G. K. Gilbert. U. S. Geographical and Geological Survey of the Rocky Mountain Region, J. W. Powell in charge. 160 pp. 4to, with plates, maps, and sections. Department of the Interior. Washington, 1877. Although this date makes the printing of the Report to have been done in 1877, the volume has been issued within three months.

"Vermilion Cliff" and "Shinarump" groups, and has a thickness of 2,930 feet; and the Upper Carboniferous. These strata in the mountains are intersected by dikes of trachyte rising from a mass of trachyte below. The dip of the strata varies from zero at top and at base to various angles between, being even 80° in some of them just above the base; but the rocks beneath the plain around them are horizontal.

The quaquaversal dip in the strata appears to indicate, as Mr. Gilbert states, that the dome-like elevations were produced through force acting directly beneath each; and, from the position of the trachyte, the natural inference is drawn that the force was connected with the eruption of this igneous rock. In the ideal sections given, one of which is here reproduced, a mass of trachyte is represented occupying an oven-shaped cavity, with the strata bulged upward above while horizontal below. The trachytic mass is called a *laccolite*, from *λάκκος cistern*, and *λίθος stone*. (Since the termination *ite* is distinctive in science of names of *kinds* of minerals and rocks, the modified form of the term, *laccolith* (analogous to *monolith*) would be better, and is used below as essentially Mr. Gilbert's.)

2.



Ideal section of a Laccolith.

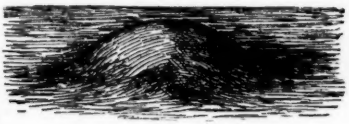
The laccoliths are flat, or nearly so, below, as was found to be true at eleven localities, showing that it had taken the form of the surface on which it rested. The thickness or height is sometimes over 3,000 feet; and the breadth is, on an average, seven times the height, but in one case only three times. The trachyte dikes which rise from it are much more numerous than might be inferred from the ideal section; and they often come up between the beds as well as intersect them. The sandstone above and below the trachytic mass, or adjoining the dikes, is usually more or less altered by the heat for a thickness of a foot or more. The erosion which has reduced the original domes to deeply gorged mountain peaks and ridges has in some of them exposed part of the interior laccolith so as to show its original surface, while in one the whole stands bare, but much eroded through the action of waters.

The chamber occupied by the laccolith was in all cases made along a shaly layer in the formation, where the cohesion was least. The trachyte is a compact porphyritic variety, wholly destitute of any trace of cellules. There are faint indications of three or four successive beds in some of the masses.

In further explanation of these peculiar mountain structures, the following sentences and illustrations are cited from Mr Gilbert's Report.

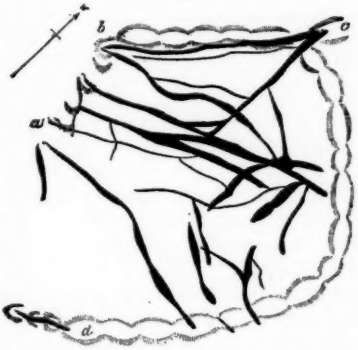
In *Mt. Ellsworth* "from all sides the strata rise, slowly at first, but with steadily increasing rate, until the angle of 45° is reached. Then the dip as steadily diminishes to the center, where it is nothing. A model to exhibit the form of the dome would resemble a round-topped hat; only the level rim would join the side by a curve instead of an angle, and the sides would not be perpendicular, but would flare rapidly outward. (See fig. 3.) The base of the arch is not circular but is slightly oval, the long diameter being one-third greater than the short. The length of the uplift is a little more than four miles; the width a little more than three miles, and the height about 5,000 feet. The curvature fades away so gradually at its outer limit that it is not easy to tell where it ends, and the horizontal dimensions assigned to the dome are no more than rude approximations." "Dikes and sheets abound from the crest of the dome down to what might be called its springing line—the line of maximum dip. At the center, dikes are more numerous; near the limit, sheets. The central area is crowded so full of dikes, and the weathering brings them so conspicuously to the surface, that the softer sedimentaries are half concealed, and from some points of view the trachyte appears to make the entire mass." The above diagram (figure 4) "shows the arrangement of the dikes in one of the outer amphitheaters of the mountain, where they are less complicated than in the central regions."

3.



Restoration of Mt. Ellsworth.

4.



Ground-plan of trachyte-dikes on the western flank of the mountain.

"The trachyte masses and the altered rocks in contact with them are so much more durable than the unaltered strata about them that they have been left by the erosion in protuberances. The outcrop of every dike and sheet is a crag or a ridge, and the mountain itself survives the general degradation of the country only in virtue of its firmer rock-masses. Nevertheless, the mountain, because it was higher than its surroundings, has been exposed to more rapid erosion, and has been deprived of a

greater depth of strata. From the base of the arch there have been worn 3,500 feet of Cretaceous, and from 500 to 1,500 feet of the Jura-Trias series, which is here about 3,000 feet thick. From the summit of the arch more than 2,500 feet of the Jura-Trias have been removed.

"The strata exposed high up on the mountain being older than those at the base, and the dip being everywhere directed away from the center, it is evident that the mountain is surrounded by concentric outcrops of beds which lift their escarpments toward it."

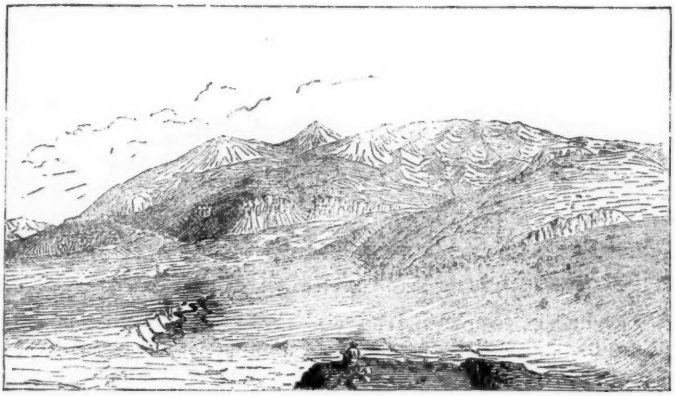
"The laccolite of Mount Ellsworth is not exposed to view, but I am nevertheless confident of its existence—that the visible arching strata envelop it, that the visible forest of dikes join it, and that the visible faulted blocks of the upper mountain achieved their displacement while floated by the still liquid lava. The proof, however, is not in the mountain itself, but depends on the association of the phenomena of curvature and dike and sheet with laccolites, in other mountains of the same group."

The Hillers laccolith "is the largest in the Henry Mountains. Its depth is about 7,000 feet, and its diameters are four miles and three and three-quarter miles. Its volume is about ten cubic miles. The upper half constitutes the mountain, the lower half the mountain's deep-laid foundation. Of the portion which is above ground, so to speak, and exposed to atmospheric degradation, less than one-half has been stripped of its cover of arching strata. The remainder is still mantled and shielded by sedimentary beds and by many interleaved sheets of trachyte." "All about the eroded (south) face of the mountain the base is revetted by walls of Vermilion and Gray Cliff sandstone, strengthened by trachyte sheets. At the extreme south, these stand nearly vertical (80°), and their inclination diminishes gradually in each direction, until at the east and west bases of the mountain it is not more than 60°." "The same beds which form the revet-crags on the southern base constitute also some of the highest peaks. Since these rest directly upon the laccolite, it is assumed that the next lower beds of the stratigraphic series form its floor." "It is noteworthy that wherever the sedimentaries appear upon the mountain top they are highly metamorphic. But in the revet-crags [upturned Jura-Trias sandstone about the south side] there is very little alteration."

The *Mount Ellen Cluster* (map, p. 17), having a diameter from north to south of more than ten miles, contains, if rightly understood, no less than sixteen laccoliths "in the spurs and foot slopes and marginal buttes" about the central crest. A view of the western flank of the mountain is shown in figure 5. In this view, there are recognized, in front of the highest

portion, the remains of three laccoliths: to the left the "Geikie" laccolith; along the middle portion (S) the "Shoulder" laccolith, overlapping the base of the Geikie; and to the right (N) two miles to the south of the Geikie, is the "Newberry arch," the last making a knob 1700 feet high, standing by itself. In the rear is the pyramidal Ellen Peak; to the left of it, in the distance, is the "Marvine" laccolith; and, to the right, still

5.



Part of Mount Ellen from the west; highest point 11,250 feet.

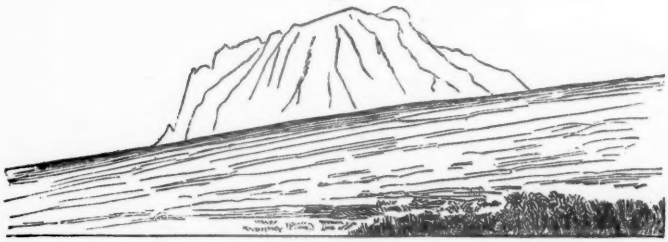
another, named the F laccolith. Lewis's Creek cuts across a flank of the Newberry arch and "exposes a portion of the [trachytic] nucleus," overlaid by 100 to 200 feet of shale, and this by the Henry's Fork conglomerate. Erosion has also exposed on two sides the interior trachyte of the Geikie laccolith. The high crest or central region of Mount Ellen is intersected by dikes of trachyte; moreover, Cretaceous shales are "baked to clinking slate," and sandstones are "greatly indurated," and there are beneath "perhaps the remains of laccolites."

The *Marvine laccolith*, one of the Mount Ellen group, "surrounded by nothing firmer than the Tununk shale and Tununk sandstone [Cretaceous], has suffered a rapid denudation, in which nearly the whole of its cover has been carried away without seriously impairing its form. It stands forth on a pedestal, devoid of talus, naked and alone. The upper surface undulates in low waves preserving the original form as it was impressed on the molten mass. Over a portion there is a thin coating of sandstone, the layer next to the trachyte being saved from destruction by the induration acquired during the hot contact. From the remainder this also has disappeared, and the contact face of the trachyte is bare." The extreme

depth of the laccolith is 1,200 feet, and its diameters are 6,000 and 4,000 feet.

In the *Jukes laccolith* "the trachyte has a depth of only one thousand feet, but it lies so high with reference to the general degradation that it is a conspicuous feature of the topography. The edges of the laccolite are all eaten away, and only the central portion survives. All of the faces are precipitous. The cover of shale or sandstone has completely disappeared, and the

6.



Jukes Butte, of the Ellen Cluster, as seen from the northwest.

upper surface seems uneven and worn; but a distant view (figure 6) shows that its wasting has not progressed so far as to destroy all trace of an original even surface. The eminences of the present surface combine to give to the eye which is alligned with their plane the impression of a straight line. The hill is loftier than the laccolite, for under the one thousand feet of trachyte are five hundred feet of softer rock which constitute its pedestal, and by their yielding undermine the laccolite and perpetuate its cliffs."

The laccoliths are described as occurring at different levels, between beds of the Carboniferous, Jura-Trias, and Cretaceous formations. The lowest in stratigraphical position, Mount Ellsworth, is 4,500 feet below the level of the highest; and it was probably covered originally by at least 7,000 feet of strata exclusive of the Tertiary. But since the Tertiary, according to Mr. Gilbert, probably spread over the region, and owes its absence only to subsequent denudation, the total thickness, since that of the Tertiary is 3,500 to 7,000 feet, may have been much over 10,000 feet.

The facts brought out appear to sustain Mr. Gilbert's conclusion that the mountains were made such, out of horizontal strata, by the ascending trachyte, which "insinuated itself between the strata, and opened for itself a chamber by lifting all the superior beds." (p. 19).

The steps in the early part of the history are given as follows on page 95 of the Report.

"When lavas, forced upward from lower-lying reservoirs, reach the zone in which there is the least hydrostatic resistance to their accumulation, they cease to rise. If this zone is at the top of the earth's crust they build volcanoes; if it is beneath, they build laccolites. Light lavas are more apt to produce volcanoes; heavy, laccolites. The porphyritic trachytes of the Plateau Province produced laccolites."

"The station of the laccolite being decided, the first step in its formation is the intrusion along a parting of strata, of a thin sheet of lava, which spreads until it has an area adequate, on the principle of the hydrostatic press, to the deformation of the covering strata. The spreading sheet always extends itself in the direction of least resistance, and if the resistances are equal on all sides, takes a circular form. So soon as the lava can uparch the strata it does so, and the sheet becomes a laccolite. With the continued addition of lava the laccolite grows in height and width, until finally the supply of material or the propelling force so far diminishes that the lava clogs by congelation in its conduit and the inflow stops." "A second irruption may take place either before or after the first is solidified. It may intrude above or it may intrude beneath it; and observation has not yet distinguished the one from the other. In any case it carries forward the deformation of cover that was begun by the first, and combines with it in such way that the compound form is symmetric, and is substantially the same that would have been produced if the two irruptions were combined in one. Thus the laccolite grows by successive accretions until at length its cooled mass, heavier and stronger than the surrounding rocks, proves a sufficient obstacle to intrusion."

The lifting force was thus due to the forced upward-flow of the lava; and it became able to overcome the resistance from the weight and cohesion of the rocks above by spreading into an opening between the horizontal strata, and widening the area of pressure.

The force communicated to the lavas at their source below was hence sufficient, it would appear, to throw a stream, in spite of friction along the passage and the density of the material (at least 2·33 in fusion), for an unknown number of miles, up to the laccolith level; and sufficient at this point, further, to lift, in the case of the lowest of the laccoliths, a superincumbent mass of beds 10,000 feet thick (supposing the Tertiary at top 3,000 feet of it) and 2·25 in average specific gravity (equivalent in pressure to 675 atmospheres) to a height of 5,000 feet.

The Report offers no views as to the origin of the propelling force. Whatever the source, it is possible that some accession of energy may have come from vapors derived by the ascending lavas from subterranean moisture or waters encountered on their way up, though slight compared with the vast amount received from action below.

The idea in the commencement of the above citation—that hydrostatic pressure determined the level of the laccolith among the strata—is dwelt upon at length in the preceding pages of the Report. The author argues that the relation as to density between the liquid trachyte and the several associated stratified rocks, and between the latter among themselves (the several densities of which he gives), is the chief cause determining the level among the strata of the laccoliths; saying that the lava, free to move upward or laterally, will intrude itself among the strata at a point "so placed that every combination of superior beds, which includes the lowest, shall have a less average density, and every combination of inferior strata, which includes the highest, shall have a greater density, than that of the lava." "If the fluid rock is less dense than the solid, it will pass through it to the surface, and build a subaerial mountain," or "volcano;" if more dense than the upper portion of the solid rock, the fluid will not rise to the surface, but will pass between the heavy and light solids, and lift or float the latter." Cohesion in the rocks modifies the result; but, he says, nevertheless, after discussing this point, "we are led to conclude that the conditions which determined the results of igneous activity were the relative densities of the intruding lavas and of the invaded strata; and that the fulfillment of the general law of hydrostatics was not materially modified by the rigidity and cohesion of the strata."

We refer to the report for a full explanation of this part of Mr. Gilbert's theory. To the writer, his explanation appears to be complete, without reference to this difference of density. With so powerful a forced movement in the lavas as the facts, if they are rightly interpreted, show to have existed, no other cause could be needed for a flow to the surface in case of an open channel, or for a flow to any level in the strata at which a fissure might terminate; and this is true, whether the lava be light or heavy. In fact *heavy* lavas, having a specific gravity of 2·85 to 3·1, make the larger part of modern volcanic cones, as well as of non-volcanic igneous outflows, and one of the lighter lavas—trachyte, of the specific gravity 2·61, by Mr. Gilbert's determination—made the laccoliths.

These lighter lavas are adapted to the purpose because they are the least fusible of ordinary igneous rocks; and they owe their difficult fusibility to the orthoclase feldspar which is the chief constituent, whose fusibility on Von Kobell's scale is marked 5, while that of albite is marked 4, and of labradorite and volcanic augite, 3. Such lavas are hence easily chilled and thicken greatly in the upper part of narrow fissures or of volcanic conduits, and it is for this reason that they have often made steep-sided *domes* over subaerial vents.

If the first step in the history of the laccoliths was the making of intersecting fissures narrowing upward, some reaching to the surface, it may be, and others to different levels in the strata, the trachytic lava passing up would tend to become thickened by cooling, or might even become solidified, in the upper part of such fissures, because of the large extent of the cooling surfaces as compared with the amount of liquid. But along their intersections it would be most sure to remain liquid, and here conduits would become localized, from which the upward forced liquid rock might spread laterally, whatever the height, and produce the laccolith. The ready cooling of the trachyte would tend to limit the lateral flow of the lavas in such chambers, and so aid in producing the thick form of the laccolith, besides preventing a waste of energy. With intermissions in the flow, the trachyte of the chamber would be intermittent in its enlargement, and receive that degree of bedded structure which, according to Mr. Gilbert, exists.

The facts give some hints as to the source of the great force producing the upflow of lavas in non-volcanic fissure-ejections. They make the vast extent of such outflows, as those over California, Oregon, India and other regions, intelligible. Volcanoes are small outlets compared with fissures that extend for miles, and the forces they command are feeble compared with the action which makes such fissures. The opening of one or more great fissures is the initial step in the making of a volcano; and the volcano is the open chimney or vent left after the fissure-action had spent its force—a point illustrated by the writer in his account of the Hawaiian islands and their volcanic origin.* J. D. DANA.

ART. IV.—*Some Thoughts on the Glycogenic Function of the Liver.* II. *Disposal of Waste;* by JOSEPH LECONTE.

[Read to the National Academy of Sciences, October 30, 1879.]

IN my previous paper,† I attempted to show that the well known and remarkable fact that nearly the whole food absorbed from the alimentary canal is distributed through the liver before it reaches the general circulation, is proof that, in a very important way, the liver prepares the food for the uses to which it is applied in the animal body: and further that the preparation is accomplished by the glycogenic function. According to my view there are three sources of glycogen, viz: 1. The whole of the amyloids: these are arrested in the liver as glyco-

* Expl. Exp. Rep. Geology, 1849. † This Journal, xv, 99.

gen and re-delivered as liver-sugar, little by little as required, and burned. 2. *Albuminoid excess:* this is split into a combustible portion (glycogen) which is delivered to the blood as liver-sugar and burned, and an incombustible portion which is either urea or rapidly sinks into urea and is eliminated by the kidneys. 3. *Waste tissue:* this is also split in the liver and disposed of like the last. There are the same three sources of vital force and animal heat, viz: 1. the combustion of the whole of the amyloids; 2. the combustion of the combustible portion of albuminoid food excess; and 3, the combustion of the combustible portion of waste tissues. Therefore the function of the liver is to prepare *all* the fuel of the body, and this fuel is only liver-sugar.

Now it has been brought to my attention that my account of the disposal of waste is in conflict with the usual view of physiologists, which view is supported by many facts. Let us then state sharply the difference.

According to the usual view, oxygen taken in at the lungs is carried by the arterial blood to the tissues, there seizes with avidity upon these at the moment of their decomposition, changes them into CO_2, H_2O and urea; and then these final products of combustion only are carried by the venous blood to be eliminated by lungs and kidneys. According to my view on the contrary, waste tissue is not burned or changed into final products at once, but circulates as incombustible matter dissolved in the blood, is carried to the liver, and there prepared for final combustion and elimination, and only thereafter does it unite with oxygen to form CO_2 and H_2O. We see the contrast; which view is right?

There are some facts which strongly support each view. The usual view that waste tissue is burned at once and only the final products of combustion circulate in the blood, is supposed to be sustained: 1. by the fact that the change from bright to dark blood, the exchange of oxygen for carbonic acid, and therefore the combustion, takes place principally if not entirely in the capillaries and therefore in contact with the tissues; and 2, by the additional fact, that increased activity of any organ, e. g., a muscle, is attended with increased heat, increased waste, and therefore presumably of increased *combustion of waste.* But, on the other hand, my view is sustained by the experiments of Schiff, already alluded to in my previous paper. These experiments prove in the most positive manner, that poisonous waste is carried to the liver and there decomposed and made comparatively innocuous.

Here then are two incontestible facts: 1. The combustion of waste takes place principally, if not wholly in the capillaries and therefore in contact with the tissues. 2. The waste is not

burned as such, as soon as formed, but must be carried to the liver to be prepared for final combustion. These two facts must be brought together and reconciled. I think this may be done as follows:

First, it must be remembered that *waste* is but a *small fraction* of the material used as fuel, by far the larger portion of such material being *food* which never becomes tissue at all, viz: *amyloids* and *albuminoid excess*. Now these also, although they, or the fuel made from them, are confessedly carried and burned in the blood, are burned principally in the capillaries and therefore in contact with the tissues. The reasons then, for burning combustible *food* principally in the capillaries, would equally apply to burning combustible *waste* in the same place, and therefore the fact that combustible waste is burned principally in the capillaries is no argument that it is burned as soon as formed. Evidently then the question is not one which concerns the combustion of *waste* alone, but the combustion of *all* fuel. The question is, why does combustion of the combustible portion both of food and waste, take place, and therefore both heat and other forms of force are generated, in the capillaries and in contact with the tissues? The *final* cause is, indeed, plain enough; it takes place there, because *there* the force is wanted; but what is the *physical* cause, or the process which determines this result? There are probably several.

1. The blood is much *longer time* in the capillaries than in any other portion of its course, and therefore even if the *rate* of combustion be *uniform*, the amount of combustion would be greater there than in any other place; and moreover, if increased activity, increases heat and therefore combustion, it does so because it also increases the blood-supply.

2. But probably the rate of combustion in the course of circulation is *not uniform*. It is probable that the tissues themselves are an apparatus for causing or accelerating combustion. The termination of nerve-fibers in the tissues, and the controlling influence of nerves over all functions, suggests that the discharge or the arrest of nerve-current, in some way which we do not yet understand, is the principal cause of combustion and therefore of generation of force there. Farther: it has been suggested to me by Mr. Christy, an assistant in the chemical laboratory, that the chemical process may possibly be something like this: oxygen is carried by the hæmoglobin, the fuel is carried as liver-sugar by the plasma, side by side in the same current; nerve discharge reverses the order of affinity and the oxygen immediately leaves the hæmoglobin to seize the sugar. In most tissues, such as many glands, etc., which are constantly active; and in all tissues so far as the function of nutrition is concerned, the process is continuous and under the influence of

the sympathetic or vaso-moter system. In muscular contraction, on the other hand, the discharge is powerful and periodic, and under the influence of the voluntary or of the reflex system.

3. It is probable also, nay almost certain, that the first decomposition of tissue, short of combustion, i. e. the first formation of waste, being a descensive change, a change from a less stable to a more stable condition, is itself a process by which heat and other forms of force are generated. This of course takes place only in the tissues.

My view, therefore, is briefly as follows: The liver-sugar formed from the sources already mentioned, 1st, commences to burn in the capillaries of the lungs, and 2nd, continues to burn in the course of the arterial circulation. The combustion thus far produces only *heat.* But 3rd, the main combustion takes place in the capillaries, probably under the influence of nerve-discharge, and this part generates not only heat but *other forms of force* characteristic of the peculiar tissue. But the fact that the main combustion takes place in contact with the tissues, has misled physiologists to believe that the tissues themselves are burned.

It seems to me that physiologists do not even yet sufficiently appreciate the function of the blood as a reservoir. The blood must be regarded as a reservoir not only for oxygen and carbonic acid, but also and still more for *food*, for *fuel* and for *waste.* It is now well recognized as a reservoir for oxygen and carbonic acid, but not sufficiently for food and waste. The tissue-food of to-day, is not used for building to-day; but the blood is drafted upon for materials for this purpose and re-supplies itself from albuminoid food. The amyloid food of to-day, is not burned to-day; but the blood is drafted upon for fuel and re-supplies itself from the liver, while the liver in its turn, re supplies itself from the amyloid food.* So also waste tissue of to-day is not mainly burned and eliminated to-day; but the blood is again drafted upon for fuel from this source and re-supplies itself from the liver and the liver from the tissues.

Finally, it will be observed that the view which I here present, as to the disposal of waste, is in some respects intermediate between the view of the old physiologists under the guidance of Lavoisier, and the usual modern view. According to the old view, waste is dissolved in the blood, carried to the eliminating organs especially the lungs, and *there* burned with rejection of the products of combustion. The lungs is there-

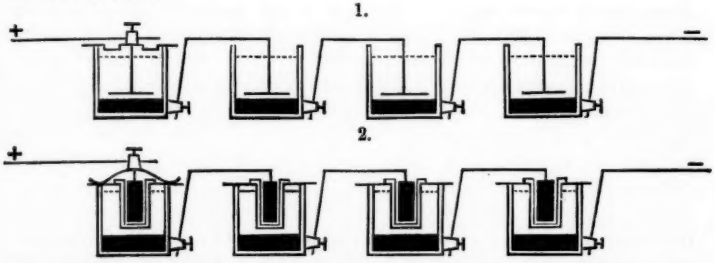
* The rapidity with which the fuel-supply in the blood is exhausted by activity and restored by food, is far greater in some insects, e. g., bees, than in higher animals. In bees, one hour of activity without food entirely exhausts, while food restores in five minutes. This is the result of the extraordinary nervous and muscular activity of these insects.

fore the furnace of the body. According to the usual modern view, oxygen is taken into the blood, is carried to the tissues, burns there on the spot the waste, and the products of combustion are then carried to be eliminated in the lungs. The old view is right in supposing that waste is carried in the blood, but wrong in supposing it to be combustible and therefore burned as soon as it meets oxygen in the lungs. The modern view is right in supposing that combustion takes place mainly in the tissues and not in the lungs, but wrong in supposing that it is the unprepared waste which is there burned.

ART. V.—*On Electrolytic Phenomena;* by WALLACE GOOLD LEVISON.

[Abstract of a paper read before the New York Academy of Sciences, February 10, 1879.

In 1866 I devised a battery in which the usual plate of zinc or other electro-positive metal is replaced by a surface of liquid sodium or potassium amalgam. It differs from any such battery to my knowledge previously constructed, in that the amalgam is perfectly fluid and its surface visible. It may be made in two forms.



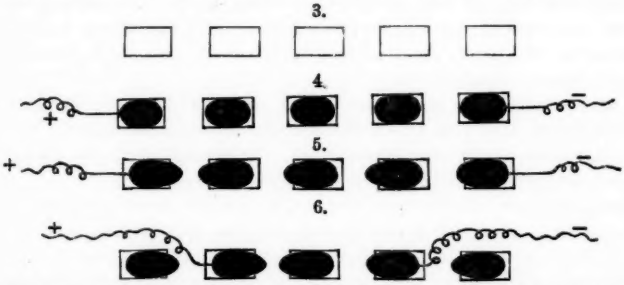
The first consists of a glass cup containing two or three centimeters in depth of 10 per cent sodium amalgam and filled with water. In this water a flat coil of platinized lead wire is suspended over the amalgam, and through a perforation in the side of the cup near the bottom a screw cup connects with the amalgam. A wire from this screw cup forms the negative pole, a wire from the lead coil the positive pole. This battery is strongly alkaline, yet gives quite a strong current. The second form is varied by substituting for the lead coil a porous cup containing nitric acid and a slip of platinum, and for the water, dilute sulphuric acid. This form of battery gives a very strong current. When several cells of the latter form are combined, on making or breaking circuit, a motion of the

amalgam is observed, which seems to arise from its being raised in the center while the current flows and its falling to the normal level when it is interrupted.

While the circuit is broken there is a constant evolution of hydrogen gas in very fine bubbles from the entire surface of the amalgam. When the circuit is closed they no longer escape freely at the point of evolution, but glide over its surface from all sides toward the center where they coalesce to form large bubbles, which there escape. These bubbles are abnormally spread or flattened out upon the surface of the amalgam, escape with a peculiar trembling as if with difficulty, and if caught under the porous cup they still exhibit the flattened aspect. On breaking the current they become hemispherical and again escape readily from all parts of the liquid surface. Some of the phenomena thus observed I have since contrived to exhibit in another form by means of the vertical lantern, using an ordinary horizontal cell five inches in diameter, which, however, is especially prepared for the purpose by cutting a groove in the glass across it just deep enough to keep a long globule of mercury in place, and slightly shallower in the middle, so as to hold two globules of mercury opposite each other. When a globule of mercury three centimeters long is held in one end of the groove touched by the negative pole of a four-cup Bunsen battery, the cell filled with dilute sulphuric acid, the positive pole touched to the electrolyte at the opposite end of the groove, and by means of an included signal key, the current sent through the circuit, the globule of mercury instantly extends. On breaking the circuit it resumes its normal form. On reversing the direction of the current by a pole changer, again closing circuit by the key, and allowing the current to pass continuously, the globule is at first agitated and repelled by the positive pole, but after a moment is again attracted. A globule at the opposite pole acts in a similar manner. Two globules at opposite poles first attract each other, on reversing current both are repelled for a moment and then being again attracted, extend toward each other. The exact amount of this attraction and repulsion may be measured by means of a perpendicular U tube containing mercury and dilute sulphuric acid over the mercury in one branch, the battery terminals being immersed in the electrolyte on one side and mercury on the other. When the current flows, the mercury column being the negative pole, it will rise toward the positive wire. On reversing the current it will be more or less repelled below normal level. A capillary tube is not necessary as it may be a centimeter in internal diameter. In all cases of attraction the globule or column seems to be constricted near the end as if it tended to part at that point and the negative

globule frequently does part throwing off a small globule which runs to the anode; in all cases of repulsion the end tends to spread or enlarge.

Fusible metal in hot solution of sodic sulphate, or dilute sulphuric acid in a glass tube, and metallic lead under fused chloride of sodium, in a grooved scorifier, in a muffle at a red heat, exhibit the same phenomena; hence they are not peculiar to mercury or amalgams. If, instead of a long groove as described, a series of five short grooves be cut (as shown in fig. 3) so as to hold five globules of mercury in a line and the end globules be touched by the terminal wires (as shown in fig. 4), on making connection they become almond-shaped (as shown in fig. 5). The positive globule extends toward the negative pole, the other four all extend toward the positive pole.



If the terminal wires be touched to the second and fourth globules, the second being positive, extends toward the negative pole, the middle and fourth extend toward the positive pole, and the end globules though not included in the circuit extend toward the center. (See fig. 6.) These are fine experiments to project before an audience, and they may be greatly varied.

In both these cell experiments small globules that lie on the plane surface of the glass move either against the rim of the cell, or in smaller semi-circles concentric with it from the positive to the negative pole, or toward the end at which hydrogen bubbles are escaping. The curves in which these globules move, may be conveniently regarded as *lines of voltaic force*, and the space between and surrounding the electrodes as the *voltaic field*. If the mercury used in these experiments contain the least trace of zinc or other metal, the phenomena will be considerably modified.

When sodium amalgam is substituted for pure mercury as the negative globule in the single globule experiment, it is always at first repelled as though it had previously been the negative terminal, and then the poles had been reversed.

When pure mercury is thus employed as the negative globule under sodic sulphate, it becomes sodium amalgam, and the violent agitation which accompanies the repulsion of the globule on reversing the current is probably due to the rapid oxidation of the occluded sodium.

When, however, sulphuric acid is used as the electrolyte, the globule could only occlude hydrogen. Since in the latter case it acts in a somewhat similar manner, it is possible that hydrogen is thus occluded, and from its rapid oxidation arises the agitation of the globule on reversing the current. The question might perhaps be decided by the Sprengel pump.

Two platinum electrodes delicately suspended near together in dilute hydric sulphate, will repeatedly attract each other, and at the moment of contact fall apart again, each separation being accompanied by a bright spark. Two plates of carbon delicately suspended are perceptibly attracted when they form the electrodes in dilute hydric sulphate or other electrolyte of a 20-cell Bunsen battery.

The attraction of solid electrodes may be due merely to the escape from them of gas bubbles, but the motion seems to be simultaneous with the closing of the circuit and to precede momentarily the evolution of the gas.

The currents in the electrolyte, to which most previous observers have attributed the movements of the globules of mercury, may be beautifully shown by projection on a screen if a number of globules between the poles are held in depressions in the rubber bottom of an ordinary upright clamp cell.

I have given a great deal of consideration to the phenomena described in this paper and to the views of those who have studied them, and though I am not able to give expression to the law by which they are governed, I can not accept any suggestion as yet advanced. I believe, however, that they offer the way to an important discovery, perhaps the mode of transmission of the electric current, when the methods of exhibiting them herein described, the abnormal behavior of gas bubbles in the sodium amalgam battery, the movements of metals and alloys other than mercury itself, the transmission of globules across the voltaic field, the mode of measuring the attraction and repulsion unimpeded by capillary force, and the movements of solid electrodes, attract the attention of observers provided with recent facilities for experimentally examining them, and that the results may lead to the complete development of a series of phenomena that have long awaited investigation.

ART. VI.—*Notice of New Forms of Fossil Crustaceans from the Upper Devonian Rocks of Ohio, with descriptions of New Genera and Species;* by R. P. WHITFIELD.*

IN the 16th Report of the State Cabinet of New York, there is described and figured a peculiar bivalve crustacean from the Hamilton formation of New York, under the name *Ceratiocaris punctatus.* It is again repeated on Plate 23, fig. 7, of the Illustrations of Devonian Fossils, Section Crustacea, under the name *Ceratiocaris* (*Aristozoe*) *punctatus.* Among the fossils of the Ohio Geological Survey, there are represented three species of similar form, but specifically distinct from the above; and I have seen examples of at least two species from the Hamilton and Chemung groups of New York, which may be distinct from any of these.

These fossils differ from the true type of *Ceratiocaris* in so many particulars, and to so great an extent, that it is quite impossible to include them in that genus. The reference to *Aristozoe* Barrande, is, however, still more erroneous, as the forms to which that name is applied are true *Ostracoides*, having all their parts concealed within the carapace, as in the *Leperditia* and its allies; while the forms under consideration are provided with a bivalve or, at least, a two-sided carapace, which incloses the thoracic portions; while the abdomen and caudal parts are naked, or not inclosed within this covering; and are more properly classed among the *Phyllopods.*

That this latter character, the naked abdomen and caudal plate, pertains to these organisms, is abundantly proven by the Ohio specimens now under consideration. The fossils are found inclosed in small concretions; and there would be but little chance for specimens, or parts of specimens of different species, or, less likely, of parts of individuals of distantly related generic forms, to be inclosed in the same small concretion; so we may safely conclude, that, where parts or fragments of individuals of corresponding size are found in the same concretion, they are parts of one individual or, at least, of the same species. In the concretions in question there are two examples where parts of the naked abdomen and caudal plate with its accompanying spines, are imbedded in the concretion together with the carapace which I have classed as the same species. This I consider as ample proof that the parts belong to the one individual; and that the animal of which they are the remains, was provided with a naked body and spinose caudal appendage as in *Ceratiocaris.* It is also

* These descriptions will be repeated in vol. iii, Paleont. Ohio, with illustrations of the species. All the specimens are from the cabinet of Dr. J. S. Newberry.

stated in the Illustrations of Devonian Fossils that one specimen resembling *C. punctatus* has been found with a body similar to that called *C. armatus* attached to the carapace, showing their individual relations.

The several species above mentioned, while differing greatly from *Ceratiocaris*, possess features in common which at once characterizes them as a natural group, sufficiently marked to be readily distinguished. I therefore propose to recognize them as a distinct genus under the generic name ECHINOCARIS, possessing the following characters:

ECHINOCARIS, new genus.

Carapace bivalve, valves subovate in outline; united on the dorsal margin by a straight hinge; the anterior, basal and posterior margins rounded, and generally more or less produced posteriorly. Surface of the valves marked by a more or less distinctly elevated, curved, longitudinal ridge, centrally or subcentrally situated; also by one or more (usually three) vertical ridges, or ridge-like nodes, extending downward from the hinge-line upon the body of the valve, and usually situated anterior to the middle of the length. Abdomen naked, composed of several segments (four known) and a caudal plate, which is produced into an elongated spine with a lateral, movable spine on each side. Posterior margin of the abdominal segments bearing spines on the now known species. Type *Echinocaris sublevis* Whitf.

Among the genera now known and referred to the *Ceratiocaridæ*, there are several distinct types of structure, indicated by the features of the carapace alone, independent of the changes which take place in the abdominal segments and in the caudal spine and appendages. The following synopsis of some of their characters may serve to illustrate their peculiarities and to show more distinctly the relations which *Echinocaris* bears to other known genera.

1st section: Carapace more or less elongated, with a straight or slightly arched dorsal line; anterior end sharply rounded or pointed (rostrate); posterior end truncate; sides convex, smooth or simply striate, sometimes marked by a simple ocular node near the antero-dorsal margin; no ridges or other nodes. *Ceratiocaris* McCoy, 1849; *Caryocaris* Salter, 1862; *Hymenocaris* Salter, 1852; *Solenocaris* Meek, 1872; (?) *Colpocaris* Meek, 1872. The last somewhat questionable in character.

2d section: Carapace similar in form to that of section 1, with the postero-basal angles produced into spines, and the surface with longitudinal ridges. *Dithyrocaris* Scouler (=*Argas* Scouler).

3d section: Carapace rounded at both extremities, elongate-

elliptical or elongate-ovate in form, with a straight dorsal margin; surface concentrically striate, no nodes or ridges. *Lingulocaris* Salter, 1866.

4th section: Carapace triangular, dorsal margin straight; surface punctate or reticulate, and concentrically striated (growth lines?). *Dictyocaris* Salter, 1860.

5th section: Carapace suboval or subovate, with a straight hinge-line: surface marked with longitudinal ridges or representative nodes and ridges; surface of parts smooth, punctate or pustulose. *Echinocaris*, new gen.

6th section: Carapace broadly oval or ovate; no straight cardinal line, consequently no hinge; anterior end rostrated or beaked; surface destitute of nodes or ridges. *Physocaris* Salter, 1860.

7th section: Carapace composed of three pieces, or apparently of three, two of which are semi-circular, with the anterior end of each obliquely truncate, forming, when the two are united, an anterior triangular notch into which the third or rostral plate is inserted; surface concentrically marked by growth lines; no nodes or ridges. *Peltocaris* Salter, 1866; *Discinocaris* Woodward, 1866; *Aptichopsis* Barrande, 1872; *Pterocaris* Barrande, 1872 (not Heller, 1862).

It will be readily seen, from the above synopsis, that *Echinocaris* differs materially in the features of the carapace from all the other genera enumerated. The features of the abdomen and caudal parts are not as reliable as those of the carapace, but are somewhat distinctive, as may be seen by the following table of comparison. (A mark of interrogation indicates that the parts are unknown or only partially known.)

Genus.	Abdominal segments.	Caudal spines.
Ceratiocaris	5 or 6 smooth	3
Dithyrocaris	1 smooth	3
Hymenocaris	8 smooth	6
Dictyocaris	6 smooth	3?
Physocaris	5 smooth	3
Echinocaris	4 spiney	3
Discinocaris	4?	3?
Peltocaris	3 smooth	3
Caryocaris	1?	3
Lingulocaris	?	?
Colpocaris	?	3
Solenocaris	?	?
Aptychopsis	?	?

The number of segments here allotted to any given genus indicates the maximum number of naked segments known: some of them contain species having a smaller number, and in some a much greater number exists, some of which are concealed within the carapace. Thus *Ceratiocaris* is known to possess in one species fourteen segments in the abdomen, only six of which are naked.

The genus *Dithyrocaris* McCoy is described as having three longitudinal ridges on the carapace. This feature is seen only when the two valves are pressed open as in McCoy's example, so as to present the appearance of one large plate; in which case the hinge-line forms the middle ridge.

The third or rostral plate in *Peltocaris*, *Caryocaris*, *Discinocaris* and *Aptychopsis*, would appear to be quite analogous to the small rostral plate seen in *Ceratiocaris*, and supposed to exist in *Dithyrocaris*, and perhaps some others, but which is usually absent. It is possible many of the forms may have possessed this rostral plate, at least among those that are deeply notched in front when the valves are spread open. In this case they would as properly be considered as having three plates in the carapace as those grouped under section 7. The forms of this section are usually found with the carapace spread open on the rock, and are then circular and discoid, but when in their natural position would have been more or less roof-shaped.

Colpocaris Meek presents some features which raise a question as to its true affinities. The longitudinal crenulated line and the inflection of the supposed ventral border do not seem to be properly understood; and I am of the opinion it may belong to a different group of Crustaceans.

ECHINOCARIS SUBLEVIS, n. sp.

Carapace obliquely subovate in general outline, the height equal to two-thirds the length, widest and deepest behind the middle, the posterior portion projecting obliquely backward and downward beyond the extremity of the hinge-line; dorsal-line straight, forming a hinge-line two-thirds the length of the valve; outer margin of the valves, except on the dorsum, bordered by a narrow, slightly raised and thickened rim; anterior border nearly vertical from the extremity of the dorsal line, for about one-half the width of the valve, except a very slight rounding backward to the hinge-line above; below it slopes abruptly backward to and along the basal line, and again more abruptly curving around the posterior end of the valve and forward to the extremity of the cardinal line; below which it is distinctly excavated. The portion of the valve which projects beyond the hinge is nearly or quite equal to one-third the length of the valve. Surface of the valves convex, and marked by ridges and tubercles. The principal ridge commences at about the anterior third of the valve, and just above the middle, as an elevated, rounded and nearly vertical ridge; but soon bends somewhat abruptly, and is directed backward in a broad, sweeping curve, at less than one-third of the height of the valve from the lower margin, and gradually decreasing in strength ter-

minates a little within the margin opposite the longest part of the valve. A second and slightly stronger ridge rises from just behind the middle of the length of the hinge, descends with a gentle forward curvature, and terminates near the upper anterior end of the first one. The anterior or principal tubercle is large and distinct, and situated near the antero-dorsal angle of the valve, occupying the greater part of the space between the front margin and the two ridges just described. Between this and the second ridge, the surface is elevated, forming a low tubercle. The surface of the anterior tubercle is occupied by several small but distinct pustules, and the entire surface of the valve is covered by a minutely granulose structure.

Abdomen apparently consisting of four free segments; the first one being short and much thicker than the others on the anterior end, but rapidly narrowed posteriorly; the posterior margin being armed with several small spine-like tubercles. The other three segments are shorter than wide, gradually decreasing in strength and increasing in length backward, the first of the three being apparently less than half as long as wide, their posterior margins all spine-bearing; a long, curved spine on each side, with three short ones between, and all increasing in length backward from the first or anterior segment.

Telson proportionally large, of a general triangular form, but slightly protruding at the origin of the movable spines, and projected behind into a long, slender, and apparently cylindrical spine, making the telson with its spine about as long as the four free segments together. Lateral spines cylindrical, very gently curved, and standing at an angle of about forty-five degrees to the central spine. Surface of the telson highly convex and somewhat angular at the origin of the spine. Surface of the crust of the abdomen smooth.

This species is closely allied in the form of the carapace to *E. punctatus* (*Ceratiocaris punctatus* Hall, 16th Rept. State Cab. N. Y., p. 74, plate 8, fig. 1), but differs in the form of the nodes and ridges, and in the surface structure; also in wanting the projection at the posterior end of the hinge, if this feature is natural on that specimen. It is probable that the abdomen and telson figured on the same plate under the name *Ceratiocaris armatus* belongs to the same species as the carapace of *E. punctatus*, as suggested by Professor Hall in the explanation of plate 23, section Crustacea, Illust. Devon. Fossils; and if so, the distinction between these two parts of the two species is much more marked than between the carapaces.

Formation and locality.—In small calcareous concretions in the Erie shales (Portage and Chemung), at Leroy, Lake County, Ohio.

ECHINOCARIS PUSTULOSA, n. sp.

Carapace ovate, widest anterior to the middle, the greatest height equal to three-fourths of the length; hinge-line straight, rather more than half as long as the valve, while nearly one-third the length of the valve projects behind its extremity; margin of the valve bordered by a narrow, thickened rim; anterior end of the valve slightly excavated below the hinge extremity, and the margin broadly rounded in front; posterior end more pointed, while the basal line is broadly and evenly curved. At the posterior end of the hinge the margin is also slightly constricted as in front. Surface of the valve convex and marked by the characteristic nodes or ridges. The principal ridge commences in an oval node, which is situated just within the anterior third of the length of the valve; is placed vertically, just above the middle of the height, and the horizontal portion, which is sharply elevated and slightly curved, is situated almost in the middle of the width, and terminates a little less than one-fourth of the length from the posterior extremity. The second ridge commences at the hinge-line near the middle of its length, and descends with a slightly forward direction to within a very short distance of the top of the vertical portion of the principal ridge. The anterior ridge, corresponding to the anterior node or tubercle of *E. sublevis*, is narrow and nearly vertical; of a slightly sigmoid form, and originates near the anterior extremity of the hinge-line; the lower end reaching more than one-third the depth of the valve. The surface of the ridges and of the valve in the postero-dorsal field, as also of the space below the principal horizontal ridge, is marked by correspondingly large and distinct postules. Abdomen and telson unknown.

This species differs from *E. sublevis* in its slightly broader form, and in the want of the obliquity of the axis of the valve with the hinge; in the narrower posterior extremity, pustulose surface, and in the form of the surface ridges; most notably in the anterior one being ridge-like and vertically sigmoid instead of round. The individual used in description is half an inch in length and three-eighths of an inch in its greatest height.

Formation and locality.—In calcareous concretions in the Erie shales, at Leroy, Lake County, Ohio.

ECHINOCARIS MULTINODOSA, n. sp.

Carapace elongate-subovate, about twice as long as high, rounded in front and somewhat pointed behind; the basal line straightened along the middle portion and parallel to the hinge-line; cardinal line straight and nearly half as long as the length of the valve, and a little nearer the anterior than to the posterior end of the carapace. Margin of the valves

bordered by a narrow, elevated, thickened rim, which is expanded considerably in width around the anterior end of the valve, and terminates in a rounded, elongated ridge at the posterior extremity of the hinge; from which point the ridge is directed obliquely forward and slightly downward from the cardinal line. The surface of each valve is divided into three slightly elevated areas, with depressed sulci between; an anterior, a central and a posterior one. The first is situated in the middle of the anterior end of the shell; the central one unites with the anterior one below, and extends along the basal margin behind, in a narrow curved point below the posterior one, and projects upward near the center of the valve in a triangular form, terminating in an elevated point just above the median line; the posterior and largest area is ovate in form, and occupies a little less than one-half the length of the shell, is narrowed in front and pointed behind, taking the form of the extremity of the shell. The center of the anterior area is slightly tumid. Along the hinge-line and just below its margin there are three subangular tubercles or nodes, at nearly equal distances and of nearly equal strength, except that the posterior one is prolonged at its base into a low, rounded and slightly curved elevation, which extends to near the point of the central raised area before mentioned. These three nodes, together with the oblique, ridge-like one terminating the marginal rim, border the hinge-line on each valve. General surface of the valve finely punctate, but most distinctly so on the posterior field.

The elongated form of the carapace readily distinguishes this from any of the other species described, while the number of node-like ridges is a very marked feature. The abdomen and telson of this species have not been observed, although several imperfect carapaces, mostly showing parts of both valves, have been obtained.

Formation and locality.—In calcareous concretions in the Erie shales, at Leroy, Lake County, Ohio.

Associated with the Entomostraca, above described as from the concretions of the Erie shales of Ohio, are the remains of a *Macrouran Decapod*, which appears to differ so much from any described genus as to make it undesirable to refer it to any of them. One of its peculiarities consists in the possession of a pair of very strong antennal appendages which project from beneath the anterior end of the thoracic carapace, of such size and strength as to raise considerable doubt as to their true nature. The existence of five thoracic limbs, exclusive of these, projecting from beneath the carapace on one side would seem to place their pedal nature out of the question; while their great development as seen on the specimen would indicate that they had served some purpose other than simple antennæ, and to raise the

question as to the possibility of their having been chelate at their extremities. As only the basal portions of these organs are represented, however, this question cannot be satisfactorily determined. Having had an opportunity of consulting Dr. A. S. Packard, Jr., in regard to them, he gave as his opinion, that from their position and the representation of the other five pairs of thoracic members without them, they could not be other than antennal in their functions, notwithstanding their great size and anomalous character. Taking this view of their nature, the specimen would conform strictly to the type of Macrouran Decapods.

In its generic relations, as well as in its general expression, the specimen resembles most nearly the genus *Pygocephalus* of Professor Huxley, first given in the Quart. Jour. Geol. Soc. London, vol. xiii, p. 363, 1857, with figures and descriptions of three specimens, under the name *P. Cooperi*. Neither the genus nor species were well characterized at that time. It is, however, again referred to in vol. xviii, p. 420, of the same Journal, and a figure given of a specimen supposed to be of the same species, much better preserved, from the Coal shales at Paisley. There are, however, too many limbs represented as originating from the thorax for a Decapod; and the antennæ, although represented as of large size, are not like those of the Ohio specimen, while there is a second pair shown. In other parts the figure is indistinct, and in the description the parts are not defined sufficiently for close comparison. The differences, however, are so great that I shall propose for this form the new generic name PALÆOPALÆMON, with the following diagnosis.

PALÆOPALÆMON, new genus.

A Macrouran Decapod crustacean, having a shrimp-like body, with a thoracic carapace narrowed but not rostrate in front, and keeled on the back and sides. Abdomen of six segments terminated by an elongated, triangular and pointed telson; segments arched; pleura smooth, not expanded nor lobed; their extremities rounded. Sixth segment bearing caudal flaps, one on each side, composed of five visible elements, the outer four apparently anchylosed to form a single large triangular plate on each side of the telson. Thoracic ambulatory appendages elongated, smooth and filiform, except the upper (second) joint, which is laterally compressed. Abdominal appendages short, the upper joints flattened or convex anteriorly, as if for the attachment of plates or fimbria. Antennæ with the basal joints strong and well developed, of large size, much exceeding in strength any of the thoracic limbs. Eye-peduncles short. Type *P. Newberryi* Whitf.

This is, so far as I am aware, the most ancient Decapod crustacean yet recognized, and on that account alone is of great interest. The character of the caudal plates, in having the parts combined to form a solid plate on each side of the telson, is also an interesting feature, if rightly understood. From the impression of the plate as seen on the ventral side, it was at first supposed to be of a single element only, but on obtaining an impression in the fragment of rock, chipped from the top or dorsal surface, the obscure lines of the first and second joints were detected, while the outer three are only traceable from the very slight difference in the surface character of two of them, and the thickened substance of the third or marginal one. Of the thoracic limbs only parts have been seen, and of the abdominal members the three anterior ones on one side; the others being concealed by the rock. The abdominal appendages are inclined backward from their point of origin, while in most of the allied living forms as *Atyoides*, *Regulus*, *Pandalus* and others, they are inclined in the opposite direction; but this is not necessarily of importance. The eye-stalks appear to have been very short, judging from the spherical cavities beneath the anterior extremity of the carapace, which are small, close together and shallow.

The earliest form of Decapod crustacean previously described, so far as I can ascertain, is given by Mr. Salter in the Quart. Jour. Geol. Soc. London, vol. xvii, p. 531, 1861, as *Palæocrangon socialis*, said to be from the Lower Carboniferous limestone of Fiefshire, Scotland. There is another supposed Decapod, *Gitocrangon*, noticed by Richter (Beiträge Paleont. Thuring.), from the Upper Devonian, which is mentioned by Salter, but of which he says he is doubtful if it be a crustacean at all. I have not seen the work in which the original description occurs, and can only judge of its nature from Mr. Salter's remarks.

Palæopalæmon Newberryi, n. sp.

Body slender, the carapace forming a little more than one-third of the entire length, higher than wide, narrowed anteriorly and truncate behind; being longer below than above; median line carinate, with a second carina on each side a little below the crest; anterior end not rostrate but obliquely truncate, and sloping rapidly backward above the truncation, forming, when looked upon in front, a narrow, elongated shield-shaped and slightly depressed area, obtusely pointed above and rapidly widening at the base, the lateral carinæ rising from the lower angles; lower posterior angles rounded; basal margins gently curved throughout and bordered by a narrow, thread-like band with a narrow groove within it. Abdomen moderately robust, highly arched along the dorsal line, the

pleura curving inward below, giving a cylindrical form. Pleura broadly rounded at their extremities on the anterior face, but slightly angular on the posterior corners; posterior margin of the segments strongly arching forward on the back. Telson elongate triangular, a little less than twice as long as wide, somewhat angular above and marked by a central ridge below, and by a backward curving, transverse ridge across the widest part. Caudal flap large, forming a triangular plate on each side, the first and second joints short sub-triangular; marginal plate of the flap thickened, narrow and elongate; central plate narrowly triangular, a little longer than wide: third or inner plate of equal length with the second and a little wider than the marginal one; the three combined as one, being apparently anchylosed at their margins to form a solid piece. Antennæ very strong, the first joint half as long as the thorax, slightly swollen in their lower half, and flattened on the under side; the other portions unknown. Thoracic limbs very slender and only of moderate length, the second joint laterally compressed, making the height nearly double the width; other joints apparently cylindrical. Abdominal limbs known only by their second (?) joints, which appear to be triangular in form, widening below, flattened and plate-like in character or slightly convex on the anterior face. (In one case only, a single thread-like appendage can be seen, as if projecting from the outer lower angle.)

Surface of the carapace marked by very fine, tortuous and interrupted, raised lines, strongest anteriorly and running obliquely upward and backward; also by a single slender, distinct, raised ridge, extending more than one-fourth the length of the carapace, originating at the lower anterior angle and passing upward and backward, with a bifurcation at the anterior third of its length. Surface of the abdomen essentially smooth. Caudal flaps marked by impressed lines increasing in number and fineness from above downward.

ART. VII.—*Upon an Optical Method for the Measurement of High Temperatures;* by E. L. NICHOLS, Ph.D. (Göttingen).

IN a previous paper* a series of experiments upon the nature and intensity of the light emitted by glowing platinum were described. It is proposed in this article to discuss more fully the results then obtained, and to develop from them, so far as is at present possible, an optical method for the measurement of

* On the Character and Intensity of the Rays emitted by Glowing Platinum, vol. xviii, Dec., 1879.

high temperatures. This method depends upon our ability to obtain, from results such as are recorded in Table IX of that paper, a general expression for the radiating power of any given body as a function of the temperature, or, what amounts to the same thing, to find the values of the quantities, A, E and I, in Kirchhoff's equation

$$e = \frac{E}{A} = I\frac{w_1 w_2}{s^3} \qquad (1)$$

These quantities being given, the temperature of a source of light could be determined by comparing the intensity of portions of its spectrum—as for instance those lying between λ and $\lambda+d\lambda$, λ' and $\lambda'+d\lambda'$, λ'', and $\lambda''+d\lambda''$, &c.—with the corresponding wave lengths of the spectrum of a body of known temperature and of known emissive and absorptive capacity. Here, as in my former paper, are to be understood by the terms "absorptive and emissive capacity," the qualities A and E, as defined by Kirchhoff.* Such a method, even though its accuracy be limited to that attainable in other spectrophotometric determinations, would bring into the field of quantitative research, a domain in which, so far as temperature is concerned, accurate measurements have been hitherto unattainable.

M. Crova, in *Comptes Rendus*, has suggested a similar method. He gave, however, no measurements of glowing temperatures upon which to base his method, and ignored entirely the very serious difficulties to be overcome before it can be made practically available. M. Crova proposes the following three modes of procedure :

1. "Au moyen de la longueur d'onde de la radiation qui limite le spectre vers le violet."†

2. "Par la position du maximum calorifique du spectre qui se rapproche d'autant plus du violet que la température d'émission et plus haute."

3. "Au moyen du rapport de l'intensité lumineuse d'une radiation déterminée λ, pris dans le spectre de la source, à l'intensité de cette même radiation du spectre d'une source de température connue, comparée au rapport des intensités lumineuses d'une autre radiation λ' dans ces deux mêmes spectres."

". . . . La mesure vigoureuse des températures pourra être faite par voie spectrometrique des que l'on counâitra la loi exacte de l'émission pour toutes les radiations et des constantes numériques pour chaque longueur d'onde. . . . ."

In the first method, the visible spectrum is falsely assumed to have a clearly defined boundary at its end nearest the violet.

* Kirchhoff, Untersuchungen über das Sonnenspectrum, Anhang, § 2.

† Crova, Etude spectrométrique de quelques sources lumineuses; Comptes Rendus, lxxxvii, 322.

In point of fact the "*limit of the spectrum*" admits (see vol. xviii, p. 400) of no sharp determination, depending as it does upon the constantly varying condition of the observer's eye.

If, as is commonly supposed, the position in the spectrum of the thermal maximum were a function of the temperature, the second method would be at best practically applicable to but a few of the most intense sources of light. Some recent discoveries of Dr. Jacques in Baltimore,* seem to show that the position of the thermal maximum depends upon the molecular weight of the glowing body, and that, for a given source of light, its position is in no way affected by a change of temperature. This newly discovered fact renders Crova's second method useless. I shall show presently that aside from Jacques' experimental evidence there are good reasons for supposing the position of the thermal maximum to depend upon the nature of the glowing body rather than upon its temperature.

The third method coincides with that which I have proposed. The chief difficulty in the development of it lies in the varying values of the emissive and absorptive capacity of different bodies.

In Equation (1) the fraction $\frac{E}{A}$ is to be sure independent of the nature of the body in question; not so, however, the quantities E and A, considered separately. That A, possesses for different substances widely different values we know from former researches. Hitherto, however, these experiments have been confined to ordinary temperatures, and the question of the dependence of this quantity upon the temperature has been for the most part neglected.

For the purposes of general discussion it is convenient to divide all bodies into four classes.

I. Bodies for which A=Constant, for all wave lengths and for all temperatures.

II. Bodies for which A varies with the temperature, but has the same value for all wave lengths.

III. Bodies for which A varies with the temperature and possesses different values for different wavelengths, but for which the ratio of these values in any two spectral-regions λ to $\lambda+d\lambda$ and λ' to $\lambda'+d\lambda'$ is independent of the temperature.

IV. Bodies for which A varies with the temperature and wave length and for which the above-mentioned ratio is also a function of the temperature.

Black bodies are, by definition, of the first class. Whether bodies exist for which A=Constant <1, can only be determined by special experiment. To the second class belong

* Distribution of Heat in the Spectra of various sources of Radiation. Cambridge, 1879.

bodies which absorb all colors in equal proportion. They appear colorless when nearly transparent, white or gray when opaque, according to the intensity of the light falling upon them and to their reflecting power. That many transparent bodies belong to this class and not to class I, is evident from the fact that although they remain transparent and colorless at temperatures above that at which metals are red hot, it is possible by heating them still further to cause them to glow brightly. Such a change in the power of emission corresponds to an increase in absorptive capacity.

That in general the absorptive capacity of other than black bodies cannot be a constant quantity may be inferred from the usual equations for the intensity of the reflected ray. Let the body in question be opaque. Of all rays falling upon it one portion will be reflected, the remainder absorbed. It has however been proved that such bodies are in general transparent when taken in sufficiently thin layers. The rays must therefore instead of being converted into heat at the surface, force their way to a certain depth into the interior of the body, and we are justified in assuming that refraction occurs. Let r be the angle of refraction, and i the angle of incidence of a certain pencil of light falling upon the substance. Let the intensity of the incident ray = 1. Whatever the character of its vibrations—provided only that in accordance with the accepted theory they be transversal—the ray can be resolved into two components, the one polarized in the plane of incidence, the other perpendicularly to it. Let e_p and e_s be the amplitudes of these components the intensities of which are denoted by f_p and f_s. Then

$$f_p=e_p^2,\ f_s=e_s^2;$$

The amplitudes of the reflected portion of the component e_p will be

$$B_p=e_p\frac{\sin(i-r)}{\sin(i+r)} \tag{2}$$

and its intensity,

$$R_p=f_p\frac{\sin^2(i-r)}{\sin^2(i+r)} \tag{3}$$

The amplitude of the other part of the reflected ray will be

$$B_s=e_s\frac{\tang(i-r)}{\tang(i+r)} \tag{4}$$

and its intensity

$$R_s=f_s\frac{\tang^2(i-r)}{\tang^2(i+r)}. \tag{5}$$

The expressions (3) and (5) approach 0 as a limit when the values of r and i are made to approach each other. In other words, when the optically denser medium becomes less dense

the intensity of the reflected ray diminishes, and a larger portion of the incident ray is absorbed.

We know that in the case of liquids their refractive index increases with their physical density, and that generally it changes for other bodies with change of temperature. The change in the index of refraction is however equivalent to a change of optical density and of the quantity $(r-i)$; so that we may expect, for all bodies for which Fresnel's formula holds, a change in the intensity of the reflected ray and consequently of the absorptive capacity for every change of temperature.

Those substances, at the surfaces of which so-called "metallic reflexion" occurs, are not included int his argument, since the formulæ do not apply to them. They would have to be considered in the lack of further knowledge as possible exceptions to the law.

For such bodies MacCullagh,* making use of the hypothesis of an imaginary angle of refraction, assumed for r the following expression:

$$\sin r = \frac{\sin i}{m}\cos\chi + \sqrt{-1}\sin\chi. \qquad (6)$$

$$= \frac{\sin i}{n}(\cos^2\chi + \sin^2\chi)$$

which admits of the common definition of n

$$n = \frac{\sin i}{\sin r},$$

since even for an imaginary angle,

$$\cos^2 r + \sin^2 r = 1.$$

In a similar manner MacCullagh assumes

$$\cos r = \frac{\cos i}{m'}(\cos\chi' + \sqrt{-1}\sin\chi'), \qquad (7)$$

where m' and χ' are functions of m and χ.

Substituting these values in equation (3) we obtain,

$$R_p = {}_pf\frac{(m'^2-m^2)^2+4m'^2m^2\sin^2(\chi-\chi')}{(m^2+m'^2+2m'm\cos(\chi-\chi'))^2}$$

To cause R_p to disappear we must set $m=m'$ and $\chi=\chi'$. MacCullagh determined experimentally the values of m and χ, but I know of no researches from which to draw any conclusions concerning the influence of temperature upon these quantities.

Cauchy† gives for R_p the following expression,

$$R_p = f_p\frac{\sin^2(i-r)+\gamma^2\sin^2 r}{\sin^2(i+r)+\gamma^2\sin^2 r}, \qquad (9)$$

* MacCullagh, Proceedings of the Irish Academy, i, 2, 159; ii, 375.

† Cauchy; Comptes Rendus, ii, 427; viii, 553–658; ix, 727; xxvi, 86.

making use of the hypothesis that the intensity of the refracted ray within the metal, diminishes in geometrical progression from the surface inward. Here as in the equations for ordinary reflected light, R_p depends upon the quantity $\sin(i-r)$. In what manner r is influenced by change of temperature has never been experimentally determined.

I have found, experimentally, the value of A for platinum at 1650° C (of the Pt. thermometer). At this temperature the spectrum afforded by glowing platinum is similar as regards the relative intensity of its various wave lengths to that of the flame of a petroleum lamp. Such a lamp-flame, the luminous rays being emitted by hot particles of carbon, answers most nearly of any available source of light the definition of a black body glowing at a constant temperature.

A flame of this kind is far from being opaque. It is quite possible under proper conditions to read fine print through it, so that in this respect the flame differs from a perfect, "*black body.*" I measured in the following way the transparency of the petroleum flame which I wished to use in the experiments about to be described.

Suppose such a flame to be brought into position before the spectrophotometer so that a certain pencil of rays would fall upon the slit. Were the flame perfectly transparent, a second precisely similar one and equally bright would, if placed behind the first flame, double the intensity of the above mentioned pencil of rays. Were on the other hand the first flame perfectly opaque, all rays reaching it from the second flame would be cut off, and the light arriving at the slit would suffer no increase in brightness.

The nearest approach to a second precisely similar flame is the real image of the first one. This image would be, when of the same size, of weaker intensity than the flame itself; but its other properties should, provided the mirror absorb all wave lengths of light in equal proportion, coincide perfectly with those of the flame.

I illuminated both halves of the slit of the spectrophotometer with two common petroleum lamps with *flat* burners. Before the lower flame, was adjusted a system of cross-wires, of which the horizontal ones appeared as dark lines in the polarized spectrum. By means of these it was easy to tell which portion of the flame came into the field of vision. Behind this lamp I placed a concave mirror, so that a real image of the flame was cast upon the flame itself. This image was of the same size but weaker than the flame. Since the horizontal wires appeared in the spectrum of the image as well as in that of the flame, forming another set of black lines, it was possible to adjust the mirror so that corresponding portions of flame and

image coincided. The spectrum formed by the two combined was much brighter than that of the flame alone, and it was easy, having measured the increase of intensity due to the image, to calculate how much of light reflected by the mirror and falling upon the flame, was absorbed, and how much allowed to pass through it. In making this calculation it was necessary to know: the reflecting power of the mirror, the transmitting power of the lamp chimney, and the relative intensity of the spectrum of the flame to that of the flame and image combined.

First of all the transmitting power of the lamp-chimney was investigated. The lamp having been provided with an exactly similar chimney, the spectrophotometer adjusted and the spectrum of this lamp flame having been compared with that of the flame lighting the upper half of the slit, the chimney to be examined was suspended in the path of the rays between the flame and slit, whereupon the spectra were again measured. I found that the chimney permitted the passage of 0·8573 of the light. Then the mirror was taken in hand. The lamp being moved a few centimeters to one side and the mirror turned until the image of the flame occupied the former position of the flame itself; the intensity of the resulting spectrum was measured. This gave as illuminating power of the image, 0·6509 of the flame's intensity. The lamp was then restored to its place before the slit and the mirror readjusted until those portions of the flame and image which appear in the spectral image coincided. The spectrum of this double source of light was then measured, and by repeated intervention and withdrawal of a black screen between the lamp and mirror, compared with the spectrum of the flame above. I found the ratio of flame and image combined to the flame alone, to be 1·2075 : 1. Had both flame and lamp-chimney been perfectly transparent, this ratio would have been 1·6509 : 1. The effect of the lamp-cylinder being eliminated the remaining difference is naturally to be attributed to the absorptive capacity of the flame; and we find $A = 0{\cdot}6432$.

To determine the value of A for platinum at the temperature in question, it only remained to compare the radiation of a glowing platinum wire with that of the flame. The wire having been given a temperature of 1650° (Pt. thermometer) for which the leucoscope* showed that the quality of the light emitted corresponded precisely with that from the petroleum-flame, the intensity of its spectrum was measured and found as compared with that of the flame to be as 1·198 : 1.

The value of A for platinum at this temperature is accordingly, $A = 0{\cdot}7597$.

* For the method by which the platinum wire was made to glow, and for a description of the leucoscope, see Paper I.

De la Provostaye and Desain* give as the reflecting power of cold platinum for lamp light (unpolarized), 0·677, so that for this metal when cold, $A = 0{\cdot}323$.

The difference between these values is so large, that making all reasonable allowance for the inaccuracies of both researches it seems certain that *platinum at* 1650° *has a much greater absorptive power for the rays of the visible spectrum than at ordinary temperatures.*

This experiment shows that platinum at least, of those substances affording metallic reflexion, offers no exception to the general law deduced for other bodies, viz: that A and E are functions of the temperature. The nature of this function, and the dependence of A and E upon the wave-lengths of the rays in question must be made the subject of special and extended investigation. It is an unexplored domain. Almost the only researches which give substance for a probable surmise, are those of Jacques already mentioned. The fact that the position in the spectrum of the maximum of thermal intensity is a function of the nature of the glowing substance and independent of its temperature, points to the conclusion that *solid bodies belong to the first three classes.*

The effect of temperature upon the spectra of gases has already, thanks to the interest lent to this subject by its importance in Spectrum Analysis, attracted much attention, and the existing researches admit of no doubt that in general *the gases belong to the fourth class.*

The steps necessary to the application of the results of the first article to the proposed method of measuring high temperatures are now evident. A general law for the changes of the quantity A must be experimentally determined, or failing in this, its values found for the various glowing bodies it is most desired to measure. It will then only remain to subject the results in Table IX (Paper I) to a further reduction so that they may be made to express the effect of temperature upon the rays from an ideal "black body" instead of those emitted by glowing platinum; and finally to obtain a satisfactory comparison of the platinum thermometer with the scale of the Centigrade air thermometer. Experiments to this end are in preparation by the author.

Peekskill, New York, July 1, 1879.

* De la Provostaye et Desain, Comptes Rendus, xxxi, p. 512; also, Annales de Chimie et de Physique, III, xxx, 276.

ART. VIII.—*Recent Explorations in the Wappinger Valley Limestone of Dutchess County, New York;* by Professor W. B. DWIGHT, Vassar College, Poughkeepsie, N. Y.

No. 2.—CALCIFEROUS AS WELL AS TRENTON FOSSILS IN THE WAPPINGER LIMESTONE AT ROCHDALE AND A TRENTON LOCALITY AT NEWBURGH, N. Y.

HAVING made further explorations in the limestone of the Wappinger Valley, since the publication of my former article,* I now present some of the new results obtained; and first those at Rochdale. Before doing this I would express my great obligations to Mr. R. P. Whitfield and Mr. S. W. Ford, for their cordial assistance in advising me concerning fossils of whose nature I was not confident, and in naming several which I had failed to identify.

In my former paper, I mentioned finding at Rochdale fossils of the Trenton limestone, whose names, as far as identified, were given. I have now to report the discovery also of Calciferous fossils in the Rochdale limestone belt, besides adding to the facts respecting the Trenton fossils.

The Chætetes of the Rochdale Trenton beds, composed of extremely fine columns, described as probably new, and for which the name *Ch. tenuissima* was suggested, has since been identified as in part, at least, *Stromatopora compacta* of Billings,† which Dawson has shown to be a *Chætetes*, and has named *Ch. compacta*. Since, however, the greater part of the specimens observed at this locality, although extremely fine-columnar, are yet decidedly and uniformly coarser than the particular specimens (from Pleasant Valley) which were thus identified, and as microscopic sections, which are under study by myself and others, promise to show other constant differences, I do not yet abandon the name proposed, as it may still cover the majority of these corals. I leave the subject until further investigation shall enable me to report upon it more decisively.

In addition to my former list of Trenton fossils from Rochdale, I have secured quite a number of Cyathophylloid corals: and among them, with little doubt, *Petraia corniculum*, in some specimens of which the radiating lamellæ are very well defined. I have also obtained several more specimens of *Leptæna sericea;* a large number of *Orthis pectinella*, and others which are probably *O. tricenaria;* a caudal shield of a trilobite, which has been identified by Mr. Ford as *Illænus crassicauda*, and is nearly two-thirds the size of the largest specimen figured by Hall;‡ and

* This Journal, May, 1879. † Pal. Foss., 1862, vol. i, Black River Group.
‡ N. York Geol. Rep., Pal., vol. i, Pl. 60.

a head of *Echino-encrinites anatiformis*, distorted, which must have been nearly two centimeters in horizontal diameter. The star-shaped *rays*, discernible on some of its plates, leave hardly a doubt as to its being the species mentioned, which occurs, as I have certainly found, at another locality mentioned beyond.

The *Chætetes compacta* (?) exists here in remarkable abundance, sometimes forming masses as large as a human head or larger. The *Chætetes lycoperdon* has not yet appeared in any of its forms. The abundant encrinal columns are of the small size usual in this limestone; one of them is one decimeter long and seven millimeters in width.

I have already mentioned my discovery at Salt Point, in the same Wappinger limestone belt, six miles northeast of Rochdale, and four northeast of Pleasant Valley, and also at another place two miles northeast of Pleasant Valley, of numerous univalves coiled nearly in a plane, and of small and delicate Orthocerata. Lately I have found abundant outcrops of the rock containing these fossils at *Rochdale*, in close contiguity to the Trenton exposures.

Further study of these fossils, in consultation with the able paleontologists mentioned above, with the finding of additional species, enables me to report essential progress in the study of these crystalline strata. The rock containing these fossils, wherever found, differs as a mass lithologically from the Trenton rock at the Rochdale exposure, and the difference is so marked that, as they lie apparently side by side at Rochdale, with conformable dip, the two kinds of strata are readily distinguished by a passing glance. While such lithological differences are not to be pressed as to rock-masses where these are separated by great distances, they may be of great importance, even in spots where fossils happen to be absent, in studying the rocks of a limited neighborhood. The Trenton rock here is of a dark bluish color, massive, but with some shaly portions, and generally very distinctly crystalline—that is, when it is broken, sparkling with crystalline facets about one or two millimeters in diameter. Though somewhat siliceous and traversed occasionally by siliceous veins, or containing hornstone nodules, it is neither eminently arenaceous nor closely intersected with flinty veins. Its weathered surface is simply the ordinary gray of weathered limestone. The other limestone rock, and the predominating rock of this region, is however, in general, several shades lighter than the Trenton, often of a "dove" color; it is uniformly fine-granular in structure, with visible crystalline facets an exception; and it is traversed to a remarkable degree with either an angular network of siliceous seams, or a twisted, curved, and knotted network, always suggesting fucoids, and very frequently showing an undoubtedly fucoidal nature.

Moreover its weathered surface is almost invariably white (frequently as much so as white lead), and highly arenaceous; and its fossils are, when weathered, of the same character. The fracture is apt to be much more splintery and conchoidal than that of the Trenton beds.

The fossils which in several places abound in this lighter-colored rock, do not leave us in doubt as to its nature. I have found specimens of the following identified specimens:

Ophileta complanata. This species is found at Wallace's quarry, Salt Point, and is one of the coiled univalves of that place mentioned, but not identified, in my previous article. It occurs also at the railroad cut two miles northeast of Pleasant Valley, and abundantly at Rochdale. In general appearance it resembles the figure given by Vanuxem in his New York Geological Report (p. 30), though it is often larger and more delicate in its structure than the somewhat rough figure represents. It is possible that this may be the *O. compacta*, the two species differing so slightly that some authors (as Billings*) suppose them to be only varieties of the same.

Ophileta levata. This is less numerous than the preceding, but is quite as well marked. It is found at Salt Point, and at Rochdale.

Ophileta (*Maclurea*) *sordida.* A number of specimens occur at both localities last mentioned. The ellipsoid form which induced Vanuxem to call the species Ellipsolites leaves little room for doubt.

Orthoceras primigenium. I have found perhaps a dozen specimens of this Orthoceras, all quite well marked; and from the indications of fragments, should say that it is rather abundant at both localities, but especially at Rochdale. The numerous, delicate, considerably curved septa are very distinct. Some of my specimens are from two to three inches long. In every instance they are shown in nearly central longitudinal sections.

There are other univalves like *Ophileta*, or *Helicotoma*, which I have not yet made out; and some smaller Orthocerata. The univalves from Salt Point, previously described as apparently containing septa, and which I supposed therefore might be Trocholites, are probably *Ophileta* (*levata?*) as the septa prove to be false.

These fossils often occur within the meshes of a network of fucoidal fronds, which, at Rochdale at least, assume a more or less tubular form for the stems. These may be *Buthotrephis antiquata*, but are too indistinct to be identified satisfactorily. This rock does not contain the abundant Chætetes, the encrinal columns of the contiguous Trenton, nor any other of the fossils found in that stratum.

* Geol. Can., vol. i, p. 246.

The conclusion is unavoidable that the rock in question is Calciferous; and it is probable that the portions containing the *Ophileta* are the "fucoidal layers" of the upper part of the formation. The description of these layers given in Vanuxem's Report (p. 30) applies exactly to those of Dutchess County.

In carrying my investigations lately to the continuation of this limestone belt across the Hudson River, I received information from Mr. J. N. Weed, Cashier of the Quassaic Bank of Newburgh, N. Y., of a fossiliferous locality near that city. It has proved to be very rich in fossils, both as regards number and variety. Their presence here has certainly been known to one prominent geologist; but it was evident that no careful examination had been made, as there was scarcely a mark of a chisel, and the most interesting specimens had been left undisturbed. The locality is 2¾ miles north from the Newburgh ferry, on the road leading to the brick-kilns on the river, and opposite to the property of Dr. W. A. Culbert. The place is between four and five miles in a northeasterly direction from the quarry (D. Miller's) where R. P. Whitfield discovered, in July last, specimens of *Maclurea magna* of the Chazy. It is a sloping rock-face about twenty feet high and two or three hundred feet long, directly on the road, at the point where it first comes in sight of the river. The rock is a dark crystalline limestone with the dip easterly 40°, and the strike N. 35° E. It is a mass of small encrinal columns and of fine Chætetes. One of the most remarkable features is the presence of many specimens (I have collected about twenty), of an unusually large encrinal column for this geological horizon, and one never collected (I believe) in this State before. It is from one-half to three-fourths of an inch in diameter, and has been identified by Mr. S. W. Ford as *Cleiocrinus magnificus* Billings, hitherto a Canadian fossil only.

I have also found here the following fossils which are unmistakably identified (except for doubts already stated as to *Ch. compacta.*)

Orthis Lynx, several; *Orthis pectinella*, many; *Rhynchonella capax*, several; *Leptæna sericea*, several; *Strophomena alternata*, abundant; *Discina*, new species, many; *Chætetes compacta*, very abundant; *Chætetes lycoperdon*, var. *ramosus*, abundant; columns of *Schizocrinus nodosus*, abundant; head-plates of *Echinoencrinites anatiformis*, abundant.

In addition, there are probably the species *O. tricenaria* and *Petraia* (*Streptelasma*) *corniculum*, with pentagonal crinoidal columns, and some brachiopods too indistinct perhaps to be identified.

The *Discina* is one to one and a half centimeters in diameter, with an unusually conical lower value, and a nearly flat upper

one, the peduncular groove being in the conical valve. As it is evidently new, I propose for it the name *D. conica*, and reserve a full description of it, and further remarks on the locality, for another paper.

These developments establish this beyond doubt as a stratum of the Trenton limestone.

ART. IX.—*On the first Results from a new Diffraction Ruling Engine;* by WILLIAM A. ROGERS.

THE best diffraction gratings are subject to three classes of errors:—

First. The accidental errors of single subdivisions, which are, for the most part, due to the irregular motion of the ruling diamond upon a non-homogeneous metal.

Second. The periodic or systematic errors, which are a function of one revolution of the ruling-screw.

Third. Errors which depend upon the position of the nut upon the screw, and which are equivalent to a varying pitch of the screw.

The errors of this class may be due either to the form of the screw itself, to a variation in its diameter, or to an imperfect mounting of the screw. The pitch of even a perfect screw practically undergoes a slight change with every variation of the amount of the friction between the moving parts of the ruling-engine.

Let us take as a type, the magnificent rulings of Mr. L. M. Rutherfurd, executed by Mr. D. C. Chapman. These gratings easily surpass all others in their resolution of the lines of the solar spectrum. Here, the first class of errors is so far wanting that it is safe to say of a given space, that it is so nearly equal to its neighbor that the most rigid investigation with the microscope will fail to reveal any difference.

For separate, narrow and adjacent spaces then, a well-made, and well-mounted screw is subject to less liability to error than the microscopic observation with which the comparison is made, even under the manipulation of the most skillful observer.

With regard to the second class of errors, viz: those which are a function of one revolution of the ruling screw, it is to be said that the danger of their occurrence is far greater. Indeed, I am not aware that they have ever been entirely overcome. In the measures of single narrow spaces they easily escape detection. For example, suppose we have a screw having a pitch of one-twentieth of an inch, in which the first half of one revolution differs from the second half by one ten-thousandth of

an inch. Each half will then have an error of one twenty-thousandth of an inch. But this maximum value is made up of successive increments of very minute errors, starting with the zero of revolution. If the graduations are ten thousand to the inch, there will be five hundred spaces in half a revolution of the screw. This maximum value, then, of the twenty-thousandth of an inch, a quantity easily measured, will be made up of five hundred additions of the errors of the successive individual spaces. If the error is a constant one for each space, its value will therefore be only one ten millionths of an inch, a quantity far beyond the ultimate limits of measurement with the microscope. When, by one hundred successive additions, the error amounts to one hundred thousandths of an inch, it will then be barely within the limits of detection.

In Mr. Rutherfurd's screw the errors of this class are nearly overcome by giving an excentricity to the index of the screw, sufficient to neutralize them at the quadrant points of revolution; that they are not entirely eliminated is shown not only by the actual measurement of distant lines, especially at the octant points of revolution, but also by the fact that the surface-waves, resulting from the residual systematic errors, are easily seen with the unaided eye when the gratings are examined with a monochromatic flame.

In the investigations of the wave lengths of light hitherto made, no attention has been paid to the periodic errors which are a function of one revolution of the ruling-screw. Our present knowledge of wave lengths depends on the supposition that the gratings from which they were determined are homogeneous throughout their whole extent. If I am not mistaken, both Ångström and Van der Willigen, who have done the best work in this direction, obtained the value of one interval by dividing the distance between the end lines by the number of spaces. It is at least possible that the error introduced through the neglect to take into account the varying pitch of the screw, may be of appreciable magnitude. I can now only note in this connection, that when oil or grease is used as a lubricant, the curve which represents the periodic errors usually has a perceptibly different form for each revolution. The compound error thus developed introduces a class of secondary systematic errors analogous to those described under the third class.

After a somewhat careful study of these three classes of errors in connection with the ruling-engine constructed for me by Buff & Berger of Boston, I determined, about two years ago, to attempt the hazardous and costly experiment of constructing a new machine which should be capable of producing a grating homogeneous throughout its whole extent. In the execution of this work I was more than fortunate in securing

the coöperation of Mr. Chas. V. Woerd, the mechanical superintendent of the Waltham Watch Factory. My warmest thanks are also due to the manager and treasurer of the Company, Mr. R. E. Robbins, for consenting to undertake a task somewhat outside of the regular work of the factory.

To Mr. Woerd I committed the entire arrangement of the details of the new machine, after deciding upon the general principles of its construction.

The new machine is now so nearly completed that some provisional work has already been done with it. It would be premature to say that it will rule a grating absolutely without measurable errors. The resolution of solar lines must be the final test, and the decision on this point I must leave to those who may use the gratings which I hope soon to make.

I venture the assertion, however, that it is the most perfect piece of work done in this country, and I doubt if its superior is to be found abroad. I feel the more free to say this because the credit for the execution belongs entirely to Mr. Woerd and to Mr. George F. Ballou who has done nearly all of the work. This is not the place for a detailed description of the machine. I will only state the general principles on which it is constructed.

(*a.*) In the usual construction of a precision-screw, it is the custom to grind and polish the threads with fine emery by means of a lead nut, after the thread has been cut as perfectly as possible in the lathe. A definite relation then exists between the threads and the centers on which they are cut. Now in grinding and polishing, the lead nut is usually held by the hand as it traverses forward and backward, and the test of the uniformity of the threads is entirely one of feeling. But during this operation *the relation between the threads and the centers may be entirely changed*, since the action of the lead nut no longer bears any fixed relation to the centers. Hence when the screw is mounted with respect to its centers, we may always expect systematic errors of various kinds.

In the construction of the screw of the Waltham machine, an attempt has been made to avoid the errors introduced in this way. The bottom of the thread was, at the suggestion of Mr. Woerd, entirely cut away, giving entire freedom in the action of the emery upon the faces of the threads. The screw rests in semi-circular bearings, and is kept in position by its own weight. The conical ends are made of tempered steel. One end presses against a polished diamond face ground exactly perpendicular to the axis of the screw. It is kept in contact by means of a steel spring bolt working against the other end. The nut is made a part of the moving bed-plate, and rests directly upon the screw.

(*b.*) Usually the aliquot part of a revolution of the screw is, during the process of ruling, secured by means of a pawl acting upon the teeth cut upon the index. In this case one is limited to certain fixed arcs of revolution. In the Waltham machine a magnet-arm 24 inches long rests upon the axis of the screw. The end of the arm works between two movable stops. A magnet fitted to the curvature of the index is attached to the other end. Another magnet is attached permanently to the bed of the machine beneath the index. During the upward movement of the magnet-arm, the first magnet becomes firmly attached to the index, carrying it forward, an arc of revolution depending on the distance between the stops. During the downward movement of the arm the index is held in position by the second magnet.

It will be seen that the arc of revolution may be made to vary at will between zero and a value limited by the greatest distance between the stops, which in this case corresponds to a motion of a little over one thousandth of an inch in the screw-plate.

The index of the screw regulating the distance between the stops reads directly to about one millionth of an inch expressed in the corresponding motion upon the ruling screw. Since these divisions can be estimated to tenths, as small a movement as one ten-millionth of an inch can be given to the screw-plate with entire certainty *as far as the mechanical indications of this degree of precision are concerned.*

(*c.*) In order to provide for the neutralization of whatever errors might be found to exist in the screw in actual use, the following devices were adopted:—

(1.) Instead of allowing the magnet-arm to fall upon a fixed stop, it falls upon a circular templet, having a motion in revolution simultaneous with that of the index of the screw. A curvature is given to the periphery of this templet which exactly corresponds to those measured errors of the screw which depend on one revolution.

(2.) A straight templet runs parallel with the screw to which is given a curvature corresponding to those errors which depend upon the position of the nut upon the screw. This templet is supported upon a vertical fulcrum placed near one end. Since the other end is movable between guides, it is obvious that in effect the pitch of the screw can be varied at will by an easy adjustment. In practice however it is found better to secure this result by varying the distance between the stops of the magnet-arm.

The present indications are that neither of these supplemental corrections will be found necessary.

(*d.*) In the investigations of wave lengths from a given ruled grating there are certain requirements which seem to need experimental as well as theoretical research.

First. It is important to ascertain the best relation between the width of the lines and the width of the intervening spaces. In this machine, after having obtained a good line of a given width, the width of the spaces can be varied at will.

Second. All we can say of the wave-length equation $\lambda = \varepsilon \sin\theta$, is that it expresses the length of a single wave of light of a given color. When we take into consideration the conditions under which the waves reach the eye, it is at least an open question whether the form of the equation is not somewhat more complex. As an illustration, the law of refraction in passing from one thin stratum of atmosphere to its adjacent one is quite simple, but it does not follow that this law holds good for the combined strata which make up the atmosphere at a given altitude above the horizon.

In order to ascertain the effect of errors of any class upon the position of the solar-lines it seems important to determine the effect of these errors experimentally. Hence the machine has been constructed in such a way that it is possible to introduce at any point, either any single error of a given magnitude, or any combination of errors, without interfering with the remaining graduations.

The tremors communicated to the machine by the running-machinery of the factory prevent the best work; but the experiments already made justify the hope that when it is permanently mounted upon the firm foundation already prepared for it, work may be done which will contribute something to our present knowledge of wave-lengths. In this connection also, especial attention will be paid to the expression of all measured distances in terms of the standard Meter of the Archives at a temperature convenient for use. With this view a standard decimeter subdivided into 10,000 equal parts will be taken as the unit of comparison.

As a type of the character of the work already done I will close this article with a description of two glass plates ruled on different days with the same setting of the stops of the magnet-arm. The stops were set to correspond to a motion of one thousandth of an inch upon the screw. The machine was started at 10 o'clock A. M. Between 12 and 1 o'clock it remained at rest. It was also at rest during the night. Starting again at 7 o'clock the next morning it was stopped at $9^h\ 50^m$, having ruled 4001 lines, covering a space of four inches.

The plate was then removed, and another one was placed in position. The machine was again started, and this second plate was ruled under nearly the same conditions with regard to time and temperature as the first one.

Having filled the lines with graphite in order to obtain a sharper definition of the edges, these two plates were then placed face to face in a mounting of stiff balsam in the same direction as that in which they were ruled. When the lines at one end were made coincident, not only were the other end lines coincident, but every one of the 4001 lines exactly overlapped its fellow. With a power of 300 I was unable to detect a single case of deviation from exact superposition.

This experiment merely showed that the machine would rule two plates exactly alike under the same conditions, but it gave no indications with reference to the homogeneous character of the graduations. But when the plates were placed face to face in a direction *opposite* to that in which one of them was ruled, then, coincidence being made between the lines at one end, a test of the homogeneity was found in the coincidence of the remaining graduations.

This coincidence seemed to be perfect for about two inches. At that point there was an abrupt separation amounting to about one eight-thousandths of an inch. This deviation remained a constant for about one inch, when it began gradually to diminish, and finally disappeared at about one inch and one-half from the point where it first appeared.

This error is probably due to a change of temperature during the nights on which the machine remained at rest. It is rather curious, however, that the error should have taken this particular form. It is not surprising that it escaped detection when the plates were arranged as first described. In the second case, the lines were barely separated, but the separation was sufficient to enable one to measure from center to center. In the first instance the overlapping of the edges was not sufficient to attract attention.

Harvard College Observatory, October 28, 1879.

ART. X.—*Solar Parallax from the Velocity of Light;* by D. P. TODD, M.A., Assistant Nautical Almanac.

THE opposition of Mars in 1862, and the experimental determination of the velocity of light by Foucault in the same year, mark the beginning of a new era in the history of the determination of the solar parallax. Especial prominence has attached to the subject ever since, not only from its inherent importance, but also from the rapidly multiplying determinations of this constant which have been made, and the vigor of discussion that has been everywhere prevalent in scientific astronomical circles.

If the generally accredited theories of the solar parallax and inter-related facts and phenomena are true, the better class of these determinations should yield values of the parallax in consistent harmony with each other—modified only by deductive consideration of the amount of accidental and systematic error with which they are severally affected. The well known fact, however, is that even the best of these determinations appear, at present, singularly and unaccountably discordant. The solar parallax, 8″·848, derived by Professor Newcomb nearly thirteen years ago, generally replacing Encke's value, 8″·57116, was regarded with caution, only because it was considered too small—the researches of Hansen, of Le Verrier, of Stone, and of Winnecke were thought to have defined the parallax far outside Newcomb's value. Within two or three years, however, the *parallactic pendulum* has swung quite to the lesser extremity of its arc, until the true value of the solar parallax has appeared possibly below 8″·8—and that, too, with good reason. But a slight gravitation toward a central value is already beginning to show itself—and now, in reality, it is not at all possible to say that the mean equatorial horizontal parallax of the sun is so much as a hundredth part of a second different from the ancient figures, 8″·813 [27″·2 centesimal], adopted by Laplace in the Mécanique Céleste, and given by the first discussion of the Transits of Venus in 1761 and 1769.

The method of determining the solar parallax through the velocity of light, though dependent on the results of physical experiments conducted under necessarily limited conditions, has never given a value of the parallax at all inconsistent with a combination of the best of the purely astronomical determinations. And this consideration encourages indulgence of the hope that, at some time in the not far distant future, this method will define the solar parallax within very much smaller limits than astronomers have yet known. To show what the method is competent to at the present moment is the object of this paper.

I bring together all the determinations of the velocity of light which have at all the merit of trustworthiness.

I. Fizeau made the first experimental determination of the velocity of light, in 1849; his experiments, however, hardly signify more than the completion of the first great step of proving the determination to be a physical possibility. The first reliable determination was executed thirteen years later by Foucault. His work has never been published *in extenso*, but brief papers have appeared in the Comptes Rendus, vol. lv, 1862, and in Poggendorff's Annalen, vol. cxviii, 1863. The resulting velocity of light is 298,000 kilometers per second, in which Foucault expresses confidence to about one-six-hun-

dredth part. I think I shall not be regarded far wrong in assigning a probable error twice as great. This I do in consideration of the very unfavorable limitations under which the determination was executed, and quite independently of what has since become known.

II. The first determination by Cornu, related in the Journal de l'École Polytechnique, xliv cahier, vol. xxvii, 1874. The resulting velocity of light is $298{,}500^{k} \pm 1{,}000$.

III. The second determination by Cornu, related in the Annales de l'Observatoire de Paris, Mémoires, tome xiii, 1876. The resulting velocity of light is $300{,}400^{k} \pm 300$. Helmert has given a rediscussion of these experiments in the Astronomische Nachrichten, vol. lxxxvii, 1876. His interpretation assigns the velocity 299,990 kilometers, the probable error of which I have estimated at 200 kilometers.

IV. The first determination by Master A. A. Michelson, U. S. Navy.* The resulting velocity of light is 300,100 kilometers. I consider this determination of equal weight with that of Foucault, and with the first determination by Cornu.

V. The second determination by Mr. Michelson. The number of this Journal for November, 1879, contains a brief recital of these experiments. I shall adopt, for the purposes of this paper, the results given on the "corrected slip," for his second determination of this constant of velocity.

The largest result for velocity of light, 300,142 kilometers.

The smallest result for velocity of light, 299,692 kilometers.

Giving equal weight to the one hundred separate determinations, the resulting velocity of light is 299,930 kilometers per second. I find that the computed probable error of this determination is no larger than six kilometers. But, in the determination of almost no other astronomical or physical constant should we consider the computation of probable error of the final result from a corresponding number of observations quite so illusory. In consideration of all the sources of error, accidental and systematic, I think the probable error of this result may be estimated at 100 kilometers.

All these several determinations of the velocity of light are now combined as follow :—

I.	298000 ± 1000	Weight 1
II.	298500 ± 1000	1
III.	299990 ± 200	25
IV.	300100 ± 1000	1
V.	299930 ± 100	100

The resulting most probable velocity of light is

299,920 kilometers = 186,360 miles per second.

* Proceedings of the American Association for the Advancement of Science vol. xxvii, 1878.

The next step is the combination of this value with astronomical constants, for the determination of the distance of the center of the sun from the center of the earth.

(I.) Theory and observation of the satellites of Jupiter afford a determination of the time-interval required by light in traversing the mean radius of the orbit of the earth. Only two astronomically precise determinations of this interval have ever been made: the first, by Delambre, in the early part of the present century,* from a discussion of an immense mass of eclipses of the satellites of Jupiter, comprising observations from 1662 to 1802; the second, by Glasenapp, in a Russian thesis,† in which there are discussed the observations of the first satellite of Jupiter from 1848 to 1873. The results of the two determinations are as follow:—

Delambre, $493^{s}\cdot 2$; Glasenapp, $500^{s}\cdot 84 \pm 1^{s}\cdot 02$.

It is quite impossible to judge with certainty just how these two widely discordant values should be combined. The former determination rests on a much greater number of observations than the latter; but it is difficult to form a just estimate of the worth of an average last-century observation of an eclipse of a satellite of Jupiter. And, moreover, astronomers have no means of knowing the process of discussion which led the distinguished French astronomer to his result—which he has adopted in his own tables of the satellites, and which was adopted by Damoiseau in his Tables Écliptiques, published in 1836. The latter determination rests upon a mass of observations of definite excellence, which have been discussed after the modern fashion. I combine the two values giving weight unity to the first, and weight two the second. The adopted value of k is, therefore, $498^{s}\cdot 3$, which, combined with the constant of light-velocity just deduced gives the mean radius of the orbit of the earth equal to

149,450,000 kilometers = 92,866,000 miles.

If, now, we combine this result with the value of the equatorial radius of the earth derived by Listing,‡

$$a = 6377^{k}\cdot 377 \; [3\cdot 8046421]$$
$$= 3962^{m}\cdot 790 \; [3\cdot 5980011]$$

there results the mean equatorial horizontal parallax of the sun, $8''\cdot 802$.

(II.) The velocity of light, the constant of aberration, and appropriate elements of the terrestrial orbit are combined, the equation of connection being,

* Tables Écliptiques des Satellites de Jupiter, par Delambre, Paris, 1819.

† Сравненіе Наблюденій Затмѣній Спутниковъ Юпитера Съ Таблицами Затмѣній и Между Собою . . . С. Гдазенапа . . . С.-Петербургъ. . . . 1874.

‡ Neue geometrische und dynamische Constanten des Erdkörpers. Eine Fortsetzung der Untersuchung: über unsere jetzige Kenntniss der Gestalt und Grösse der Erde. Von Johann Benedict Listing. Göttingen, 1878.

$$\frac{\delta g_{III}}{\delta t}\frac{a}{\sin \pi} = V\theta \cos \varphi_{III}$$

wherein g_{III} denotes the mean anomaly of the earth,
φ_{III} the angle whose sine is the eccentricity of the earth's orbit,
θ, the constant of aberration.

Struve's constant of aberration, 20″·4451, with Listing's value of a, leads to the following results: The mean radius of the orbit of the earth equal to

149,293,000 kilometers = 92,768,000 miles;

and the mean equatorial horizontal parallax of the sun, 8″·811.

It remains to consider the probable variations of the elements of this computation, and the effect of such variations on the derived parallax. The following elements of sensible uncertainty are considered:—

(1.) Uncertainty in the determination of the terrestrial velocity of light. In the process of experimental determinations of the velocity of light, almost no sources of mechanical error have been encountered which cannot, under the most favorable conditions and methods, be reduced to a minimum. What these conditions and methods of experiment are will not now be considered. Let it suffice, for the present, to remark that in approaching the utmost refinement in a determination of such supreme nicety, experimenters are like to be confronted with modifying physical circumstances—which, in all probability, however, need not be considered in connection with any experimental determination of the velocity of light heretofore executed. For the detail of uncertain elements affecting the result of each series of experiments, reference must be had to the individual papers themselves. I am disposed to think that the limit of uncertainty of the velocity of light concluded above may be fairly taken at seventy kilometers.

(2.) Uncertainty in the coefficient of the light-equation of the satellites of Jupiter. The same circumstances, unfavorable in considering the proper combination of the two independent determinations of this constant, hold here. The amount of uncertainty is probably not far from one second of time.

(3.) Uncertainty in the constant of sidereal aberration. I conceive that a variation of 0″·025 in this well determined constant will not be regarded far from the limit of uncertainty. However, this estimate of its variation cannot reasonably be adhered to, except on the supposition that the accepted value of the constant of aberration holds for stars in every part of the celestial sphere,—that is, that the motion of translation of the solar system in luminiferous ether is not sufficiently great to affect the astronomical accuracy of determination of this constant. This question pertains to the astronomy of the future.

(4.) Uncertainty in the relation of the absolute terrestrial velocity to the velocity in space. On this matter, much difference of opinion exists. As the history of the Greenwich water-telescope shows that the constant of aberration is not affected by the passage of the light of the determining star through refracting media, this element of uncertainty exists only in the derivation of the solar parallax through the light-equation of the satellites of Jupiter. The impossibility of an experimental determination of this relation renders the assumption of identity necessary.

(*a.*) Combining the maximum velocity of light with the maximum coefficient in the light-equation, and the minimum velocity with the minimum coefficient, the following relations exist:—

Limiting k	Limiting V	Distance of Sun		Solar Parallax.
		In kilometers.	In miles.	
499″·3	299990	149,785,000	93,074,000	8″·782
497″·3	299850	149,115,000	92,658,000	8″·822

(*b.*) Combining the maximum velocity of light with the maximum value of the constant of aberration, and the minimum velocity with the minimum constant, the following relations exist:—

Limiting θ	Limiting V	Distance of Sun		Solar Parallax.
		In kilometers.	In miles.	
20″·47	299990	149,510,000	92,903,000	8″·798
20″·42	299850	149,076,000	92,633,000	8″·824

It will be remarked that all these combinations are made in the most unfavorable manner, so as to give the limiting values of the solar parallax with the variations of the elements previously adduced. The probable errors of the intermediate values of the parallax are about one-third these variations.

In conclusion, then, all the experimental determinations of the velocity of light hitherto made give, when combined with astronomical constants, the mean equatorial horizontal parallax of the sun, $8''{\cdot}808 \pm 0''{\cdot}006$.

The corresponding mean radius of the terrestrial orbit is

149,345,000 kilometers = 92,800,000 miles.

Nautical Almanac Office, Washington, Nov. 10, 1879.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On Alloys of Gallium with Aluminum.*—Lecoq de Boisbaudran has been studying the alloys which gallium forms with aluminum. If the latter metal be used in large proportion, the two must be heated pretty strongly even to a dull red. The alloys thus obtained remain brilliant, and do not sensibly attract oxygen from the air during their formation. After cooling, they are brittle and but slightly coherent. They decompose cold water, better water at 40°, with elevation of temperature, evolution of hydrogen, and the formation of a chocolate-brown powder which ultimately becomes white flocks of alumina, almost the whole of the gallium being set free in globules apparently free from aluminum. The slow evolution of hydrogen by a solid alloy is considerably quickened by contact with a globule of liquid gallium, owing to electric action. Surfused gallium dissolves aluminum even below 15°, forming very brilliant liquid or pasty alloys, which decompose water with great energy. Ordinarily this decomposition is spontaneous; but sometimes a globule of alloy is inert when thrown into water, while another fragment of the same mass is immediately active, and even renders the first so upon contact with it. On touching the liquid alloy with a fragment of solid gallium, crystals appear which are pure gallium, and which do not act on water. After their removal, the alloy is less active; but if the whole is re-melted by the heat of the hand, the alloy regains its activity.—*C. R.*, lxxxvi, 1240; *Bull. Soc. Ch.*, II, xxxii, 393, Nov., 1879. G. F. B.

2. *On the Volatility of Platinum in Chlorine.*—Several years ago, Seelheim heated a piece of thin platinum foil enclosed in a combustion tube, to full ignition in a slow current of chlorine gas, for twenty-four hours. The tube behind the foil was found covered with brilliant and very perfect crystals of platinum, whose form could be recognized by the unaided eye. To test still further the question of the volatility of platinum in chlorine gas, the author placed some platinous chloride in a small porcelain flask and raised this to a bright red heat in a furnace. After cooling, the flask was carefully broken, and the platinum was found to have sublimed, partly as a network of crystals in the neck, and partly as distinct crystals on the sides and bottom of the flask. The author thinks this experiment of importance in connection with Meyer's dissociation of chlorine; since it is not true, as the paper of Meyer asserts, that nothing but chlorine is volatilized on heating platinous chloride. Indeed the observation of Meyer that the volume of chlorine was one-third greater than at lower temperatures, is completely explained by the equation $Pt_2Cl_4 = 2Cl_2 + Pt_2$=6 volumes, two volumes being platinum vapor. Moreover the problem is still more complicated if, as the experiments of Troost and Hautefeuille have rendered probable, platinous chlo-

ride is itself volatile as such.—*Ber. Berl. Chem. Ges.*, xii, 2066, Nov., 1879. G. F. B.

3. *On the preparation of the Acetic ethers of Polyatomic Alcohols.*—FRANCHIMONT has shown that by making use of the dehydrating powers of zinc chloride, acetyl derivatives of the higher polyatomic alcohols can be obtained with ease. The carbohydrate is warmed with four times its weight of acetic oxide and a small fragment of fused zinc chloride. The acetylization is complete, as experiments with cellulose, mannite, and glycerin have satisfactorily shown.—*Ber. Berl. Chem. Ges.*, xii, 2059, Nov., 1879. G. F. B.

4. *On the Relation between Molecular Refractive Power and Chemical Constitution.*—BRÜHL has continued the investigations of Gladstone and Landolt with reference to the relation between refractive power and chemical constitution, and has obtained some interesting results. The researches of these chemists had shown that the expression $\frac{n-1}{d}$, in which n is the refractive index and d the density, possesses a value for any given substance, which is independent of the temperature. Landolt had multiplied this by the molecular weight, obtaining $P\left(\frac{n-1}{d}\right)$ which he called the molecular refractive power. For feebly refractive media n may represent any definite index, such as, for example, that of H_a, the red line of hydrogen. But in order to compare substances which are highly refractive, as to their refractive power, none of the observed indices will answer, as they are all influenced by dispersion. A refractive index not thus affected would be the index corresponding to a ray of infinitely great wave-length. This Landolt finds as follows: Calling μ_{λ_1} the index for light of wave-length λ_1 and μ_{λ_2} for that of wave-length λ_2, the formula of Cauchy gives, for substances not too highly refractive,

$$\mu_{\lambda_1} = A + \frac{B}{\lambda_1^2} \quad \text{and} \quad \mu_{\lambda_2} = A + \frac{B}{\lambda_2^2}.$$

Hence we have

$$B = \frac{\mu_{\lambda_2} - \mu_{\lambda_1}}{\frac{1}{\lambda_2^2} - \frac{1}{\lambda_1^2}} \quad \text{and} \quad A = \mu_{\lambda_1} - \frac{B}{\lambda_1^2},$$

in which B is the coefficient of dispersion and A the index desired of a ray of infinitely great wave-length. Substituting this last value for n in the formula above, we have the expression $\frac{A-1}{d}$, a constant for the same substance, dependent only upon the chemical character of the body and independent of its density and dispersion, as also of temperature. The product of this by the molecular weight, $P\left(\frac{A-1}{d}\right)$, Brühl calls the molecular refraction. The

densities and the refractive indices were determined at 20°, the former being referred to water at 4° and to a vacuum, the value being indicated by $d^{2}_{4}{}^{0}$ and carried to four decimal places. The indices for obtaining the refraction-coefficient A, were those of H_α and H_γ. In Landolt's investigations, the same molecular refraction was obtained for all isomeric bodies; thus showing that only the number of the atoms and not their arrangement influenced this constant. Hence the atoms have the same refractive power in all their compounds; and by comparing different bodies together the atomic refraction r_A for carbon was given as 4·86, of hydrogen as 1·29 and of oxygen as 2·90. Hence the molecular refraction of $C_xH_yO_z$ would be $R_A=4{\cdot}86x+1{\cdot}29y+2{\cdot}90z$. The author has now shown that the molecular grouping has an essential influence upon the molecular refraction, those atoms which are united directly to each other by more than a single bond, exert a greater influence upon the transmission of light than those singly bound. If R_A be the calculated refraction-equivalent of an unsaturated hydrocarbon, a the influence of a double union, and x the number of pairs of removed hydrogen atoms, the formula for a body represented by $(C_nH_{2n+2})-xH_2$ would be $P\left(\frac{A-1}{d}\right)=R_A+xa$. If y represent the number of pairs of hydrogen atoms removed to form a closed chain, and hence without influence optically, the formula becomes $P\left(\frac{A-1}{d}\right)=R_A+(x-y)a$. For example, in hexylene, one pair of carbon atoms is doubly united. Hence we have $(C_nH_{n+2})-H_2$, and the formula is $P\left(\frac{A-1}{d}\right)=R_A+a$. In diallyl, we have $(C_nH_{2n+2})-2H_2$ and the formula is $P\left(\frac{A-1}{d}\right)=R_A+2a$. In benzene, we have $(C_nH_{2n+2})-4H_2$; but a closed chain exists, with only three double unions; therefore $x-y=4-1=3$ and the formula becomes $P\left(\frac{A-1}{d}\right)=R_A+3a$. Experiment has fully confirmed these conclusions, which have been extended to chlorine, bromine and nitrogen which have atomic refractions of 9·53, 14·75, and 5·35 respectively. The author thus states it:—The molecular refraction of those bodies in which doubly united carbon atoms exist is greater than the value calculated from the sum of the atoms, and the excess is proportional to the number of such dual unions, being two units for one and $2z$ units for z double unions. $M_A=P\left(\frac{A-1}{d^{2}_{4}{}^{0}}\right)=R_A+2z$. But this is simply equivalent to saying that the atomic refraction of carbon is higher when doubly combined. This concedes the variability of atomic refraction, which appears to be the case not only with carbon and oxygen, but also with all poly-equivalent elements. The atomic refraction of singly united carbon is 4·86 as above; but that of doubly united carbon is 5·86.—*Ber. Berl. Chem. Ges.*, xii, 2135, Nov., 1879. G. F. B.

5. *A new method for preparing Hydrobromic and Hydriodic acids.*—Since both hydriodic and hydrobromic acids are decomposed by strong sulphuric acid, they cannot be prepared by distilling potassium iodide or bromide with this acid. They are usually prepared by the action of water upon their phosphorus compounds, a process which is tedious and inconvenient. BRUYLANTS proposes a new method for preparing these acids, founded on the fact that bromine and iodine unite at ordinary temperatures with certain organic substances to form compounds which at higher temperatures are decomposed so as to evolve hydrobromic or hydriodic acid. For this purpose he proposes the oil of copaiba, prepared by distilling copaiba balsam with water and drying. The oil boils at 250° to 255°, and can convert three times its weight of iodine or bromine into hydrogen iodide or bromide. It is put in a tubulated retort of 500 cub. cent. capacity furnished with a return condenser, to the end of which is attached a tube leading to a drying cylinder. For 60 grams of the oil, 20 grams of iodine may be used. It is dissolved at a gentle heat, and then the temperature is allowed to rise. A regular evolution of gas soon begins, and when it ceases, the retort is allowed to cool a little, and then more iodine is added, until 150 grams has been used. This quantity of iodine gives 145 to 150 grams hydriodic acid. The oil becomes for the most part solid during the reaction. Bromine is used in the same way, only with more caution. From 60 grams oil and 150 of bromine 142 grams hydrobromic acid were obtained.—*Ber. Berl. Chem. Ges.*, xii, 2059, Nov., 1879. G. F. B.

6. *Thermo-chemistry.*—JULIUS THOMSEN has published (Ber. Berl. Chem. Ges., Nov. 10, 1879), some new and very interesting results from this field of investigation.

(1) The heat of formation of the various anhydrous carbonates regarded as formed from metal, oxygen and carbonic oxide, are given as follows:

Reaction.	Heat Units.	Reaction.	Heat Units.	Reaction.	Heat Units.
$K_2 + O_2 + CO$	250,940	$Ba + O_2 + CO$	252,770	$Mn + O_2 + CO$	180,690
$Na_2 + O_2 + CO$	242,490	$Sr + O_2 + CO$	251,020	$Cd + O_2 + CO$	151,360
$Ag_2 + O_2 + CO$	92,770	$Ca + O_2 + CO$	240,660	$Pb + O_2 + CO$	139,690

If from these numbers we subtract 66,810 units—that is, the heat produced in the reaction $CO + O = CO_2$—we can obtain in each case the heat of formation of the same salts when formed from metal oxygen and carbonic dioxide; that is, in the general reaction $M'' + O + CO_2$. If now from these last values we subtract the heat evolved in the oxidation of each metal the result is the heat of formation of the anhydrous salt when produced from the metallic oxide and carbonic dioxide; that is, in the general reaction $M''O + CO_2$. The results thus obtained in a few of the more important anhydrous carbonates are as follows:

Reaction.	Heat Units.	Reaction.	Heat Units.
$BaO + CO_2$	55,580	$PbO + CO_2$	22,580
$SrO + CO_2$	53.230	$Ag_2O + CO_2$	20,060
$CaO + CO_2$	42,490		

Since the molecule of calcic carbonate weighs 100, it follows that 425 units of heat, in round numbers, are absorbed for every unit of weight of limestone (regarded as pure calcite) burned in a lime kiln. Favre and Silbermann found for the same constant the value 308 units which is ¼ too small. A comparison is made in this paper of the heat of formation of the anhydrous carbonates and sulphates of the same metal, corresponding to the general reactions $R'' + O_2 + CO$ and $R'' + O_2 + SO_2$, from which it appears that the difference is far from constant. In most cases the heat of formation of the sulphate is greater than that of the carbonate, the difference varying from 22,620 heat units in the case of the potassium salts to 3430 units in the case of the silver salts; but in the case of the salts of cadmium and manganese the conditions are reversed, and the heat of formation of the carbonate is greater than that of the sulphate. These facts are thought to indicate that SO_2 and CO, stand in different relations to the molecules of the salts, in which these radicals are supposed to exist as actual atomic groups.

(2) In his previous investigations on the heat of formation of the oxides and acids of nitrogen, Thomsen had left undetermined the heat of formation of NO, which enters as a radical into so many of this class of compounds. The determination of this important value required the construction of a special apparatus, and for this, as well as for other reasons, has been delayed. The result now reached differs greatly from that obtained by Berthelot, and, if sustained, will require a material correction of some of the most important thermo-chemical data. According to Berthelot, $N + O = -43{,}300$ units, while according to Thomsen this value should be $-36{,}395$ units. Thomsen claims that there is a large error in Berthelot's work in consequence of the circumstance that in the process used by the French chemist the quantity estimated was several times greater than the quantity measured, and the quantity measured too small to admit of accurate results under such circumstances. But the details of his own method on which his conclusions are based, are not given in the "Berichte," and he refers to an extended paper in the Festschriften der Universität zu Kopenhagen. How great a change the correction thus introduced makes in some important values calculated from the old data, the following table shows:

	Berthelot.	Thomsen.
$N_2 + O_4$	−48,660	−33,650
$N_2 + O_5 + Aq$	−51,800	−36,430
$N_2 + O_5 + Aq$	−14,800	+180

For a large number of other thermo-chemical data corrected for the new fundamental value of $N + O$, we must refer to loc. cit., page 2062. J. P. C., JR.

7. *On a New Standard of Light.*—Mr. LOUIS SCHWENDLER presents the advantage of using the incandescence of platinum by means of a constant electric current for a standard of light. In foot-notes he states that this is not a new idea and refers to Dr.

Draper's papers on radiation published in 1844. Mr. Schwendler's lamp differs in no respect from that proposed by Dr. Draper. From his experiments Mr. Schwendler concludes, that to produce the unit of light equal to the light emitted by a standard candle, from 300 to 725 units of current were necessary according to the size of the platinum strip, while with the use of the carbon electric lamp only 10 units of current were necessary. He thereupon states his conviction that "from an engineering point of view, light by *incandescence* can scarcely be expected to compete with light by *disintegration*" (electric arc). He believes that light by *incandescence* is not much cheaper than light by combustion. No reference is made to the late results of Edison on platinum submitted to alternating currents in a partial vacuum.—*Phil. Mag.*, Nov., 1879, p. 393. J. T.

8. *Report on the Electric Light.*—Mr. Louis Schwendler in a report on the expediency of lighting the railroad stations in India by means of the electric light, gives the following results of his measurements. A normal candle, six to the pound, and consuming 120 grains per hour, employs in producing the unit of light, a work of from 610 to 1365 megerga per second. An electrodynamic machine with not more than 0·1 Siemen's units resistance in the circuit, only from 10 to 20 megerga; so that one electric light produced only at one place in the circuit, is 50 times cheaper than the candle. Division of the electric light, on the other hand, Mr. Schwendler finds to be uneconomical. A dynamo-electric machine with the greatest number of divisions of the movable coil, gives the most constant current. The strength of the current increases at first quickly, then is proportional to the velocity of rotation, then increases more slowly. The electromotive force decreases with a constant velocity of rotation more quickly than the entire resistance increases, and the more quickly the smaller the interior resistance of the machine is. When the external resistance is zero, the electromotive force reaches its maximum. The following table represents the conditions in the electric are: J is the strength of the current in electro-magnetic units (webers), W the resistance in Siemen's units, and E′ the electromotive force in volts.

J	28·81	23·87	16·27	W	0·91	1·72	1·97	E′	2·02	1·91	1·86

A good dynamo-electric machine should make 700 to 750 turns in a minute and afford a current in electro-magnetic units expressed by the formula

$$J = 0{\cdot}3\sqrt{\frac{W' - w'}{R + r}},$$

where W′ and w' represent the work respectively during the production of the current and during the running of the machine on an open circuit, and R represents the inner and r the outer resistance. If $J > 20$, the loss of work reaches 12 per cent.—*L. Schwendler, Précis of report on Electric light.* London, Waterlow & Sons, 1878. J. T.

9. *Upon the Electro-magnetic rotation of the Plane of Polarization in Gases.*—KUNDT and KÖNTGEN state as the result of their investigation the following:

(1) Atmospheric air, oxygen, nitrogen, carbonic oxide, carbonic acid, illuminating gas, ethyl and marsh gas, indicate a rotation of the plane of polarization in the direction of the positive current.

(2) The amount of this rotation under like conditions is different for the different gases.

They detail the precautions employed in their research, and give the methods at length. It is found that the electro-magnetic rotation is the greater the greater the index of refraction of the gas, although the authors have not been able to determine the exact numerical law which might connect this magnetic effect with this or any physical constants of the gases. They hint at the possibility of determining the amount of rotation of the plane of polarization of air by the magnetism of the earth; and by reference to their table of results, estimate that 253 km. of air in the north-south-direction would experience under the magnetism of the earth a rotation of 1°.— *Wiedemann's Annalen der Physik und Chemie*, No. 10, 1879, p. 278. J. T.

II. GEOLOGY AND NATURAL HISTORY.

1. *A Hudson River fossil plant in the Roofing slate that is associated with chlorite slate and metamorphic limestone in Maryland, adjoining York and Lancaster Counties, Pennsylvania;* by J. P. LESLEY. (From a letter to J. D. Dana, dated Philadelphia, Dec. 6, 1879.)—Professor Lesquereux has just determined *Buthotrephis foliosa* on a slab of roofing slate from the quarries on the Susquehanna River near the Maryland line. This is a most important discovery. Professor Frazer has been studying the roofing slate belt and adjoining chlorites, for several years in connection with his York and Lancaster county work. He never found any traces of organic life, nor could hear of any. But he found several curious forms in the rocks across the state line in Maryland, one of which looked like a flattened *Orthoceras.* Professor James Hall and Mr. Whitfield were disposed to consider them not organic. They have been figured for the American Philosophical Society's Proceedings and for the Reports of the Survey. These are the only fossils ever seen in that region to our knowledge. The slab of *B. foliosa*, is in our museum and will be figured. Professor Frazer received it from a Presbyterian clergyman, professor in Lincoln University, who got it from a miner, with six or seven other larger and finer slabs which he sent to the York Museum, York county, in acknowledgment of aid from the citizens to the University. There seems to be no doubt that the slabs came from the Peachbottom quarries as asserted.

There are two species of *Buthotrephis* known in the Trenton limestone, three in the Hudson River slates, one in the Clinton. One is reported from the Devonian of Russia. Several from the sub-Carboniferous remain unstudied. *B. foliosa* is characteristic

of the Hudson River. It is in the upper part of the Hudson River formation, along the foot of the Kittatinny or Blue or North Mountain on the Lehigh River in Eastern Pennsylvania, that we have our Statington and other roofing slate quarries; and no trap is known in the neighborhood, and no reason can be assigned for excessive metamorphism of structure (not of lithology); but on the Maryland line a trap dike many miles long has been followed by Professor Frazer across Lancaster county, *passing through the* celebrated Gap Nickel mine, to and across the roofing slate belt of Peachbottom. But this belt is a number of miles long, and I can see no important connection between the trap at one end of it and its metamorphism.

Professor Frazer feels sure that the roofing slates are part and parcel of the chlorite slate formation which makes such a show along the river for miles north of the quarries. But the structure is very obscure. To the north of the chlorites, a bold double-crested anticlinal (of Toquan creek) crosses Lancaster and York counties, and is finely exposed upon the two banks of the Susquehanna River, bringing up massive gneisses, etc., evidently belonging to our Philadelphia rocks, to those of the Welsh Mountains west of the Schuylkill River, and to those of the Highlands of New Jersey and New York State.

The chlorite slates are always, with us, seen in juxtaposition with the limestones, which we feel confident are No. II ("Magnesian, Calciferous"); but the structural connection is not quite satisfactory yet. Mr. C. E. Hall is disposed more and more to look upon them as No. III (Hudson River) metamorphosed, all along the Chester county "South valley" hill, and across the Schuylkill into Philadelphia and toward Trenton.

Everything points toward non-conformable basins or outlying patches of metamorphosed Silurians in the heart of our Azoic country of southern Pennsylvania and Maryland, and this discovery of *B. foliosa* leaves very narrow room for further doubt on the subject.

2. *Pennsylvania Second Geological Survey.* Harrisburg, 1879.

(1) *Second Report of Progress in the Laboratory of the Survey at Harrisburg*, by ANDREW S. MCCREATH, MM. 438 pp. 8vo.

(2) *The Geology of Lawrence County, and a Special Report on the Condition of the Coal Measures in Western Pennsylvania and Eastern Ohio*, by J. C. WHITE, QQ. 336 pp. 8vo, with a colored geological map of the County and 134 vertical sections.

(3) I. *The Northern Townships of Butler County;* II, *a Special Survey, made in* 1875, *along the Beaver and Shenango Rivers, in Beaver, Lawrence and Mercer Counties*, by H. MARTYN CHANCE. V. 248 pp. 8vo, with four maps, one profile section and 154 vertical sections.

These additions to the series of volumes of Pennsylvania Reports, already numerous, show efficient action in both the head of the Survey and the corps who are at work with him. The first of these Reports, while mostly the work of Mr. McCreath, includes

also the following: Classification of Coals, by P. FRAZER, Jr.; Firebrick tests, by F. PLATT; Notes on dolomitic limestones, by J. P. LESLEY; Utilization of Anthracite slack, by F. PLATT. The analyses of Mr. McCreath are of coals of different coal beds, cokes, iron ores, irons, cinders, clays, fire-bricks, zinc ores, lead ores, limestones, marls, the mineral barite, and other substances, and by their number and character indicate a great amount of excellent work. They are accompanied by descriptions, and often sections, of the beds from which the specimens were taken. The results of tests of Pennsylvania and other coals for weather-waste also are given in tables. The volume is a very important contribution to the practical as well as scientific part of the great subjects of coal and iron.

One of the most important questions before the geologists of Pennsylvania is that with regard to the relation of the rocks of the western margin of the State to those of the adjoining part of Ohio, described by the Ohio geologists. Its settlement is necessary to a correct mapping of the rocks and coal beds of the two States. In Mr. J. C. White's Report, after details on the geology of Lawrence County, in which numerous careful sections are given of the coal beds and associated rocks, the results of a special study on this subject are brought out. The same point, but for a different part of the border region, is illustrated also in the Report of Mr. Chance, who surveyed "the Slippery Rock, Shenango and Beaver River valleys," in 1875, "for the special purpose of connecting the well-known Coal-measures of the Ohio River valley with the then almost unknown or very ill-understood rocks of Northern Butler and Mercer Counties. The same problem has been studied also by Mr. Ashburner, whose results will appear in a Report now in the press. These different observers, according to Professor Lesley, agree closely in their results, and thus the settlement of this question in inter-State geology is essentially accomplished.

3. *Geological Survey of San Salvador.*—The Geological and Economic Survey of San Salvador has been entrusted, by the government of that country, to Mr. W. A. Goodyear, late of San Francisco, and for some years in charge of important work on the Geological Survey of California. Mr. Goodyear sailed about the end of September for his new field of labor.

4. *A Manual of Palæontology, for the use of Students, with a General Introduction on the Principles of Palæontology;* by H. A. NICHOLSON, Professor Nat. Hist. Univ. St. Andrews. 2nd edition, revised and greatly enlarged. 2 vols. 8vo, 1879. Edinburgh and London. (Wm. Blackwood & Sons).—This second edition of Professor Nicholson's Manual of Palæontology is improved in every part, large additions of new matter having been made to its descriptions, and new illustrations introduced after the best style of the engraver's art and largely from drawings on wood by the author. The author's acquaintance with general zoology, and his labors among fossil corals and other inverte-

brate fossils, American as well as British, has well prepared him to make a judiciously arranged and convenient manual for student or instructor; and such is his work. The arrangement is zoological, commencing with the lowest forms, the Protozoans: and in connection with each section the zoological characters and relations, and the stratigraphical position or range are stated. Such general deductions as the science has established are also presented, but without wandering into speculative discussions. The numerous illustrations are well selected for showing structure and generic and family distinctions. Why the author should write *Kainozoic* for *Cænozoic* or *Cenozoic*, when he uses Eocene, Miocene and Pliocene, and not Eokaine, Miokaine, Pliokaine, is not clear. But this is a point in orthography, and does not diminish the value of the work. The mechanical execution of the work is excellent, quite in harmony with the beauty of the illustrations. All interested in Geology will find Nicholson's Manual of Paleontology a very valuable companion in their studies.

5. *Dana's Manual of Geology.* Third edition. 912 pages. 8vo. Over 1250 figures, with 12 plates and a chart of the world. New York: 1880. (Ivison, Blakeman, Taylor & Co.)—In this new edition of the Manual, the part on Kinds of Rocks has been wholly remodelled; that on Dynamical Geology has been mostly rewritten and its pages and illustrations increased in number one-half; and that on Historical Geology, while but partially revised, has received important changes in the pages on the Green Mountains, American fossil Mammals, and the Glacier and Champlain periods of the Quaternary. Through the kindness of Professor Marsh the volume contains also twelve plates: three illustrating the American Jurassic Dinosaurs; two, the two types of toothed birds of the Cretaceous, and giving figures of the complete skeleton; three, the Tertiary Mammals of the Rocky Mountain region; and, one, the relations in size of the brains of Tertiary and Modern Mammals. In addition, brief lists of works and memoirs are added, bringing out the history of opinions in connection with the Dynamics of the Science.

6. *Catalogue of Official Reports upon Geological Surveys of the United States and Territories, and of British North America;* by Frederick Prime, Jr., Assistant Geologist of Pennsylvania. 72 pp. 8vo. From vol. vii, Trans. Amer. Inst. of Mining Engineers, Philadelphia, 1879.—Since Professor Marsh's Catalogue of American Geological Reports was published in this Journal, the number of these Reports has more than doubled, and the science owes much to Professor Prime for the preparation of this new and much improved catalogue. It gives, with the titles, full details as to size, time and place of publication, names of authors of the subordinate reports of a volume, and includes, besides government reports, others of a public character. Copies can be obtained of Professor Prime (907 Walnut street, Philadelphia) in exchange for Geological Reports.

7. *Classification and Description of the American Species of Characeæ;* by B. D. HALSTED.—The earliest paper directly relating to the American *Charæ* appeared in this Journal in 1843, viz: the "*Brief Notice of the Charæ of North America*, by Prof. Alex. Braun, communicated by Dr. Engelmann." Two years later a notice of American *Charæ* appeared in a note to *Plantæ Lindheimeræ*, published in the Boston Journal of Natural History. Since that date we have only scattered references to *Charæ* in local lists and reports of different expeditions, until within the last few years when the attention of our botanists has been more frequently turned to the species of this small but interesting order. The task of determining native species will be much facilitated by two works which have recently appeared. One by Dr. T. F. Allen entitled Characeæ Americanæ, an illustrated work of which two parts have appeared, has already been noticed in this Journal. The other, originally presented as a graduating thesis at Harvard University in May, 1878, by Mr. B. D. Halsted, is now published in part in the Proceedings of the Boston Society of Natural History. There is a short introduction, giving a general account of the structure of the order, followed by detailed descriptions of the eighteen species known to the writer from an examination of the herbaria at Cambridge and a number of private collections. Of the species, eight belong to *Nitella*, one to *Tolypella*, and nine to *Chara*. One new species, *C. Robbinsii*, is described. Among the more interesting species, we may mention *N. gelatinosa* found by Ravenel in the Santee Canal, and the beautiful *C. gymnopus*, var. *elegans*, which was first found by Oakes in Essex County, Massachusetts, where it has recently been rediscovered by Mr. Robinson; and it is now known in other localities. As a whole the paper shows indications of careful study, and there is only one portion which we would criticize. The group of the *Gymnopodæ* including *C. gymnopus* and *C. Robbinsii* should be compared with *C. polyphylla* var. *Michauxii* Braun, which, as it seems to us, may have been confounded with what Mr. Halsted considers to be the typical *C. gymnopus*. It should also be compared with *C. sejuncta* Braun, a species certainly approaching *C. Robbinsii*. The literature of the old *C. Michauxii* and *C. sejuncta* is very obscure, and these two species figure unpleasantly in the footnotes of inaccessible articles. But we hope to have eventually from Mr. Halsted a further elucidation of the *Gymnopodæ*.

W. G. F.

8. *Untersuchungen über die Zellkerne der Thallophyten*, by Prof. FR. SCHMITZ.—This paper, an extract from the Proceedings of the Niederrheinische Gesellschaft, is a general review of the mode of occurrence of the nucleus in the different groups of Thallophytes. In it the author has embodied his own observations, which have been made principally in reference to Algæ. He shows that the cells of certain genera which were supposed to be without a nucleus really have not one nucleus but a large number of nuclei. He considers that multinuclear cells occur tolerably

frequently among the Thallophytes, especially in species having a siphonous thallus, whether colored (Algæ) or colorless (Fungi). In *Oscillaria*, *Ustilago* and some other genera, however, Professor Schmitz was unable to detect a nucleus. Hæmatoxyline is the reagent advised for bringing out the nuclei in doubtful cases. The article is followed by a note on the *Fructification of the Squamariæ*, which, it appears, have an arrangement of creeping filaments such as have been described by Thuret and Bornet in *Dudresnaya*. W. G. F.

9. *Le Charbon de l' Oignon ordinaire*, by Dr. MAX CORNU.—In the Comptes Rendus of July, Cornu records the appearance in the markets of Paris of the onion-smut, *Urocystis Cepulæ*. The disease which is known to have been common in Connecticut and Massachusetts for a number of years, had not been hitherto observed in France. Dr. Cornu considers *U. Cepulæ* to be distinct from *U. Colchici*. W. G. F.

10. *Entwickelungsgeschichte einiger Rostpilze*, by Dr J. SCHROETER.—This paper, which consists of advanced sheets of an article to appear in the forthcoming number of Cohn's Beiträge zur Biologie der Pflanzen, is replete with interesting facts on the development of different *Uredinei*, for the careful study of which in recent years we are more indebted to Dr. Schroeter than to any other botanist. It includes a synopsis of the European species of *Puccinia* which are found on the *Umbelliferæ*. In reading the paper, one sees at what a complicated condition the study of the *Uredinei* has arrived; and that no one but a specialist can hereafter expect to be able to understand what is written on the different transformations of this most perplexing order of plants. W. G. F.

11. *Botanical Necrology for the year* 1879.

WILLIAM T. FEAY, M.D., died at Savannah, Georgia, on the 22d of May, at the age of not far from 76 years. His remains lie in Laurel Grove Cemetery, under the shadow of the noble live oaks whose boughs are funereally draped with long tufts of *Tillandsia usneoides*, swinging mournfully in the air. This cemetery in the neighborhood of Savannah is associated in the writer's mind with this estimable botanist; for his only visit to it was in Dr. Feay's company one spring morning. We had known him in correspondence, and it was a pleasure to become personally acquainted with this most amiable man. Dr. Feay was one of those botanists who know very much and never publish anything, and who, though living a useful life, wholly fail to play the part to which they are entitled. He was born in South Carolina, studied a while at the University of Georgia, at Athens; then studied medicine at Charleston in his native State, but later turned his mind to scientific studies and to classical scholarship. It is reported that, at a critical period of life, he wasted a considerable patrimony in some excesses; and that when he came to himself and had to live by his own exertions, he chose the life of a school teacher. To this vocation, and to his botanical pursuits as an avocation, he devoted himself entirely for the rest of his life,

and for the best part of it in the city of Savannah, in charge of a private school, living alone and with utmost frugality, devoting all his earnings to the purchase of books and all his spare time to the acquisition of knowledge. During the war of the rebellion he took refuge in Florida, teaching when pupils were to be had, studying plants at all seasons, and making some interesting discoveries. Several of these commemorate his name, among them a *Palafoxia* and a pretty little *Lobelia*.

JACOB BIGELOW, M.D., far the most aged of American botanists, died at Boston on the 10th of January, 1879, at the age of 92. A brief biography was published in a preceding volume of this Journal (xvii, 263), in April last.

JAMES WATSON ROBBINS, M.D., died at Uxbridge, Massachusetts, January 9, 1879, one day before Dr. Bigelow, his only senior among American botanists, as he had reached the age of 77. A biographical notice of him appeared in the Necrology of the preceding year, in February last.

HERMANN ITZIGSOHN, a cryptogamist of considerable repute, whose name is connected with researches on the spermatozoids of the lower tribes of plants, died at Schœneberg, near Berlin, January 4, 1879, at the age of 65.

JOHAN ANGSTRÖM, a distinguished bryologist, of Sweden, died January 19th, at the age of 65.

H. W. BUEK, favorably known for his indexes to DeCandolle's Prodromus, died at Hamburg, February 10th, at the age of 83.

H. G. L. REICHENBACH, the veteran German systematic botanist and in his day a voluminous author, a man greatly respected and honored, died at Dresden, March 17, at the age of 86. The orchidologist of our time, bearing the same name, is the son, now Professor of Botany at Hamburg.

H. R. A. GRISEBACH, Professor at Gœttingen, and one of the most prominent and voluminous systematic botanists of our day, died May 9, in his 66th year. His earliest considerable work was a Monograph of the *Gentianeæ*, in 1839. His most important one, a comprehensive treatise on the Vegetation of the Earth, was published in 1872; his latest, Symbolæ ad Floram Argentinam, appeared about the time of his unexpected decease. He is well known in this country for his elaboration of the extensive collections of Charles Wright in Cuba, as well as for his Flora of the British West Indies, one of the earlier of the English Colonial floras.

THILO IRMISCH, an acute morphologist, author of many valuable papers, especially on the subterranean parts of plants, died at Sondershausen, Germany, April 28, at the age of 64.

EDOUARD SPACH, native of Strasburg, for very many years the keeper of the Herbarium at the Paris Museum, Jardin des Plantes, in the earlier portion of his scientific life a voluminous author, an acute systematic botanist, a worthy representative of the school which is disposed to multiply genera upon single characters, died May 17, at the age of 78. He had been for some time superannuated.

KARL KOCH, the prince of horticultural botanists and a most learned dendrologist, born at Weimar in 1809, explorer of Asia Minor and the Caucasus in especial reference to the origin or nativity of the long-cultivated plants of the Old World, died at Berlin, May 25, in the 70th year of his age.

DAVID MOORE, Director for the last forty years of the Glasnevin Botanic Gardens, Dublin, which he kept in unrivalled perfection, author in part of the Cybele Hibernica, of a synopsis of Irish Mosses and a Report on the Irish Hepaticæ, died June 9, at the age of 72.

EDWARD FENZL, who forty years ago was the assistant of Endlicher in the Vienna Imperial Herbarium, since Endlicher's death in 1849 the Professor of Botany and Director of the Botanic Garden at Vienna down to the year 1878, whose earlier studies were directed to the *Alsineæ* and their allies, and who published various memoirs of critical value, died September 29th, in the 72d year of his age.

JOHN MIERS, the Nestor of English botanists, died at his residence in London, October 17th, at the great age of 90. He went to South America many years ago as a mining engineer, there took up with ardor the study of botany in which he has so long persevered, made a vast number of drawings and sketches, for which he had a great facility, and in about 1840 he began the long series of his papers in systematic botany, monographical and critical, of which over fifty are enumerated in the Royal Society's Catalogue of Scientific Papers coming down to the year 1863, but whose issue continued down nearly to the last year of his remarkable life. Original in his treatment, and ready to grapple with recondite questions of affinity, in which it is not always easy to control plausible inferences by decisive tests or by intuitive judgment, the value of Mr. Miers' work must be various, and that of much of it not yet determinable. Some of it is doubtless over-ingenious, and too great trust may have been placed upon drawings prepared long before their use. But the indomitable spirit of the man, and his guileless amiability were equally and wholly admirable. A. G.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Geological Survey of the Public Domain.*—In the Congressional discussion, referred to in our former historical notice of the Department for the Geological Surveys of the National Domain, page 492 of the preceding volume, the question of an extension of the Survey into "all the States" was, as the writer finds, alluded to in its various bearings, though briefly. The form of the amendment to the bill, as it was finally passed by the House, is, in full, as follows:

Provided, That this officer shall have the direction of the Geological Survey, and the classification of the public lands and examination of the geological structure, mineral resources, and

products of the National Domain, and he may extend his examination into the States, not to interfere, however, with any Geological Survey now being made by the States."*

The vote for the amendment stood—yeas, 92, nays 53, 141 *not voting*. It thus appears that the important measure, sprung upon the House in its closing hours, unknown to, and unconsidered by, the country, *had only ninety-two votes in its favor*.

In order that the exact views of those who advocated the bill may be understood, we make a few citations from the remarks in the discussion. Mr. Atkins, its most urgent advocate, said: "Tennessee has a large deposit of coal and iron, and would be glad to have accurate information as to it." "The object that I had in offering this joint resolution was simply to enable the Geological Director to make in his next report a practical presentation of the mineral resources of the States of the Union, so far as they relate to coal and iron." "The object is to make surveys of the mineral deposits in all the States." Mr. Wilson, of West Virginia, said: "The vast mineral wealth locked up in our mountains should be developed." Mr. Haskell said "Congress does not possess the power to oust the State surveys from their work under the State laws, and this is simply to give free and full power and opportunity to give us what we need—a Geological Survey of the United States." On the other hand, Mr. Reagan, of Texas, said "I shall vote against this bill, either with the amendment or without the amendment, because I do not believe the Constitution enables me to pass such a law. We, day by day, and step by step, in advance of them [our predecessors], proceed without the authority of the Constitution in creating new sources of expenditure, and entailing new burdens on the people."

Thus the investigation of ore deposits is a chief end in view—ore deposits which belong to private individuals, not to the country. It is asked that the ore beds in Tennessee should be investigated by a United States agent, with the general government to meet the expense. The mineral resources of the country are to be investigated, not by each State for the benefit of the State and its citizens, as is done for other resources, but by the General Government. Tennessee has an able geological investigator in her own State Geologist, Professor James M. Safford, who has already studied the coal and iron deposits of Tennessee; and if appointed to the work by the State, or by any interested party, he would make as thorough and satisfactory a report on the subject as any one that is or may be connected with the Geological Survey Department under the United States, and for a small part of the sum that the general government would be likely to pay. Pennsylvania has able geologists, now at work, in Professor Lesley and the men who are associated with him in the geological survey of the State; and Professor Lesley has given more time to the subjects from a geological and geologico-economical point of view

* This and the following quotations are from the Congressional Record for June 29.

than any other person in the country. So other States have their geologists, whose labors have been much among coal and iron deposits, and who are ready to carry on any further investigations that may be made. A special agent at Washington is not wanted, unless it be that the United States Treasury is, through Congress, a more accessible source of funds for surveys than the State Treasuries. The idea that here is an open door for the supplies needed for new geological surveys would be pretty sure to give such a scheme favor among geologists.

The following are points deserving careful consideration before the amendment is passed.

(1.) Its passage will put an end to all State Geological Surveys; for, by it, the General Government appoints a Director for such surveys, and gives, thereby, an implied pledge that it will supply the funds required.

(2.) Its provisions embrace not only paleontological and geological surveys for the whole country, and surveys of mineral deposits, but surveys of the lands of the country at large with reference to Agricultural resources, and to all other points on which the value of the Public lands depend. And it might include surveys with reference to water-power along all streams with the same propriety, as these are resources of the highest importance.

(3.) All the States may go to Congress for appropriations for these various purposes, if they are granted to one.

(4.) Nearly all the States have had their Geological Surveys and have published volumes of Reports containing their results with regard to the rocks, fossils, ore beds and all mineral resources. More detailed and complete surveys could, however, in all cases be made. But it would be vastly better, that mensuration surveys should first have been carefully made, as the writer has already urged. And with respect to the ore-deposits, these are now so well known through the surveys that have been made, that what remains, even in Tennessee, may well be left to private enterprise. There is no real need for help from the General Government.

(5.) The development of the *resources* of the States being assumed at Washington, State rights and State duties would thereby be absorbed by the Central Government; and this centralization is opposed to the spirit if not the letter of the Constitution of the United States.

(6.) The expense of carrying out the provisions of the amended bill would be enormous. For the region to be covered by the detailed surveys is the whole country, and the time its accomplishment would demand would reach far into the indefinite future.

As the history of the Department of Geological Surveys is of great national interest, we publish here a copy of the estimates which Mr. King has submitted to Congress for the work of the Geological Survey Department, during the next fiscal year ending June 30, 1881.

Geological survey of iron and coal resources of public domain	$30,000.00
Extending observations on coal and iron into old States	20,000.00
Survey of agricultural geology on public lands of Mississippi Basin	25,000.00
Geological survey of gold and silver in Division of Rocky Mountains	35,000.00
Geological survey of gold and silver in Division of Great Basin	35,000.00
Survey of geological structure of public lands in Mississippi Basin	25,000.00
Survey of geological structure and classification of public lands of Rocky Mountains	30,000.00
Survey of geological structure and classification of public lands in Colorado Basin	40,000.00
Survey of geological structure and classification of public lands in Great Basin	30,000.00
Survey of geological structure and classification of public lands in Pacific	25,000.00
	$330,000.00

Thus Mr. King assumes that the proposed amendment is as good as passed, and makes his call for 330,000 dollars for his first year's expenses. The proportion for "the States" is not very large; it is a beginning. J. D. DANA.

2. *A Handbook of Double Stars, with a Catalogue of Twelve Hundred Double Stars, and extensive Lists of Measures. With additional Notes, bringing the Measures up to* 1879. For the use of Amateurs. By EDWD. CROSSLEY, F.R.A.S., JOSEPH GLEDHILL, F.R.A.S., and JAMES M. WILSON, M.A., F.R.A.S. London, 1879. (Macmillan & Co.)—No work on this subject has of late years appeared which will prove of such general acceptance to all classes of observers as this excellent handbook. Only those who have experienced delay and vexation from inability to procure the published measures of stars can fully appreciate the patient labor which the compilers have bestowed upon this volume; and though it is modestly dedicated to the use of amateurs, it is one of those books which the professional astronomer will find convenient for ready reference in the observing room.

The work (which is gotten up in excellent style, typographically), is divided into four parts: "the first part, historical and descriptive of instruments and methods; the second is mathematical; the third part contains lists of measures of the most interesting double and multiple stars, with historical notes on those which are of special interest; the fourth part is bibliographical." There is so much that is thoroughly good in this work that it seems captious to suggest any omissions: yet it is very natural for an American to ask, why is "Chauvenet's Astronomy" so persistently ignored by English equatorial observers? The book is mentioned, certainly, but his elegant methods of reducing micrometer observations are not given; nor is there any reference to his exhaustive discussion of the errors to which the equatorial is liable. The slipping piece to the micrometer box, though originally we think an English invention, is not mentioned, though it is of great value where the clock-work is not in nice adjustment and the observer

wishes to use but one micrometer-screw. Gauss's modification of Bessel's method for determining the focal length of the object-glass should have been given, because it is one of the very best methods of determining the value of the revolution of the micrometer-screw; and most observers would have liked to have something about the different eye-pieces, achromatic and otherwise, made by Steinheil, Clark and others.

The working out of orbits by both the graphical and analytical methods is an excellent feature, and it would be difficult to improve on the arrangement of the catalogue and measures. L. W.

3. *Double Star Observations made in* 1877–8 *at Chicago with the* 18½*-inch Refractor of the Dearborn Observatory, comprising,* I, *a Catalogue of* 251 *new double stars with measures, and,* II, *Micrometrical measures of* 500 *double stars;* by S. W. BURNHAM, M.A. From the Memoirs of the Royal Astronomical Society, vol. xliv.—Mr. Burnham's Memoir was received too late for a notice. It bears testimony to his ability, precision and energy as an astronomical observer. His observations make an important part of the Handbook of Double Stars, just noticed.

4. *Solar Light and Heat, the Source and the Supply: Gravitation: with explanations of Planetary and Molecular Forces;* by ZACHARIAH ALLEN, LL.D. 241 pp. 8vo. New York, 1879. (Appleton & Co.)—This is a sequel to the work published by the author in 1851, The Philosophy of the Mechanics of Nature, etc. The idea of the author is, that the revolving planets in passing through the universally diffused electric ethers generate by their motion the moving force which comes to us as light and heat. It is hardly to be expected that his views will be accepted by physicists.

OBITUARY.

Professor B. F. MUDGE.—Professor Mudge died at his residence, in Manhattan, Kansas, suddenly, on the 21st of November, of apoplexy. Professor Mudge was the State Geologist of Kansas. Only a few months since—last September—his Report on the Geology of Kansas was noticed in this Journal. Professor Mudge was a man of great industry in his favorite science, and made large collections of fossils, which were, however, sent to others to describe. Lesquereux was indebted to him for collections of Cretaceous plants from the Dakota group in Kansas, which make a considerable part of his report, and Professor Marsh for specimens of Cretaceous vertebrates. Professor Mudge thus contributed largely to the progress of American Paleontology, although not himself describing the species he collected. In 1866, a paper of his appeared in this Journal, on fossil footprints in the Carboniferous of Kansas, and another, in 1868, on a meteorite which passed over the State.

JOHN JOHNSTON, since 1835 Professor of Chemistry at Wesleyan University, Middletown, Conn., and for some years past relieved as Emeritus Professor, died at the residence of his son at Clifton, Staten Island, December 1st, 1879, in his 74th year. He was a conscientious and successful teacher of science, and papers by him on mineralogical and physical subjects will be found in the earlier volumes of this Journal.

APPENDIX.

ART. XI.—*New Characters of Mosasauroid Reptiles;* by Professor O. C. MARSH. With Plate I.

THE Mosasauroid reptiles are so rare in Europe that the type specimen described by Cuvier still remains the most perfect yet discovered there, and the only one from which important characters have been made out. In this country, however, this group attained a marvelous development, and was represented by several families, and numerous genera and species. The abundance of specimens is perhaps best illustrated by the fact that the Museum of Yale College contains remains of not less than 1,400 distinct individuals. In not a few of these, the skeleton is nearly if not quite complete, so that every part of its structure can be determined with almost absolute certainty. From this store of material, I have already made out various characters of these reptiles,* and in the present communication several others are recorded, which have escaped the attention of previous observers. The subject is by no means exhausted.

THE STERNUM.

The absence of a sternum has been asserted by Cope to be one of the important characters of the Mosasauroid reptiles,† and this statement has been accepted by some authors. Several specimens, however, in the Yale Museum, one of which is figured in Plate I, figure 1, prove the contrary, and indicate the presence of a sternum in the entire group.

The most perfect specimens of the Mosasauroid sternum preserved pertain to the genus *Edestosaurus*, and are of the true Lacertian type. The sternum in this genus is narrow, and elongate in form, and nearly or quite symmetrical, as shown in Plate I, figure 1. It is thin, slightly concave above, and convex below. Its antero-lateral margins are short and rounded, and have distinct grooves for the coracoids. The costal margins are much longer, and converge posteriorly. Each has facets for five sternal ribs, and, behind these, false ribs were supported by a partially ossified pedicle, which joined the end of the sternum. The ossification of the sternum was by endostosis.

* This Journal, vol. i, p. 447, 1871, vol. iii, p. 448, 1872.

† Vertebrata of the Cretaceous, p. 114, 1875. Also, Bulletin of Survey of Territories, p. 309, 1878.

In the other genera of Mosasauroid reptiles, the sternum has not yet been found so well preserved as in *Edestosaurus*, but there can be no reasonable doubt of its presence. In *Holosaurus* there appears to have been a partially ossified mesosternum.

The Fore-limbs.

In Plate I, figure 1, the entire pectoral arch and paddles of *Edestosaurus* are represented, essentially as found in the matrix. Hitherto, the limbs of this genus have been only partially known. The general structure of the paddle is Cetacean in type. The humerus is very short, and the radius is larger than the ulna. There are seven distinct carpal bones. The outer one of the proximal series, which probably represents the pisiform, does not assist in the support of any metacarpal. The digits are five in number, of moderate length, and much expanded. The writer has already determined and figured the fore-limb in *Lestosaurus*,* and the entire arch and paddles are here given for comparison. In this genus, there are but four carpal bones, all grouped together on the ulnar side. There are five digits, longer, and less expanded than in *Edestosaurus*.

In *Tylosaurus*, the coracoid has no emargination. The humerus, fore-arm, and entire paddle is much longer than in the above genera, and the digits were less expanded. The number of phalanges was much greater, especially in digits IV and V.

The Hind-limbs.

Since the writer discovered the posterior limbs in several genera of the Mosasauroids, and figured the pelvic arches, little has been added to the subject. In Plate I, figure 3, the complete pelvic arch and hind paddles of *Lestosaurus* are represented, the latter nearly in the position in which they were found. They are considerably smaller than the fore-paddles, but very similar in general form and proportions. The femur is more slender than the humerus, and there are but three tarsal bones, all on the outer or fibular side. There are five well developed digits, and the number and position of the phalanges are shown in the figure.

In *Tylosaurus* the hind-paddles are smaller than those in front, but their structure is very similar. All the genera of the *Mosasauroid* group have a well developed pelvic arch, and functional posterior limbs.

The Hyoid Bones.

No hyoid bones have hitherto been observed in this group, but they exist in *Tylosaurus* and *Lestosaurus*, and doubtless in all the genera. A pair of these bones was found beneath a

* This Journal, vol. iii, Plate X.

skull of *Tylosaurus micromus* Marsh, and one of the specimens is represented in the figures below, which give its main characters. The upper end is obliquely truncated, and occupied by a rugose, concave face (*a*) resembling an imperfect suture. The shaft is slender, and somewhat curved. The lower end is expanded, and has two distinct facets on the outer and inner angles (*b* and *c*), where it was attached to other bones. In *Lestosaurus* there are hyoid bones very similar in form to those here described.

1.

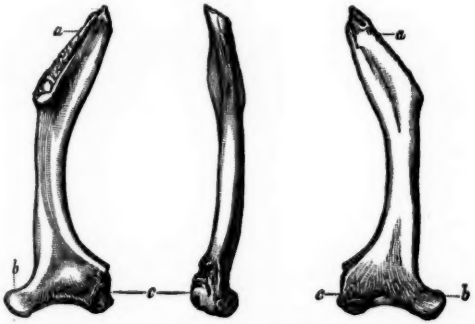


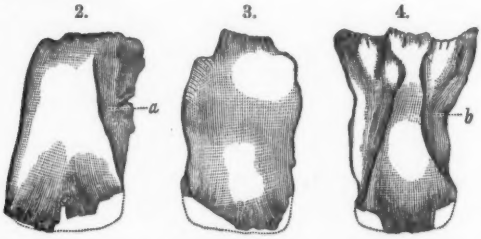
Figure 1.—Three views of a hyoid bone of *Tylosaurus micromus*, Marsh; one-half natural size.

In *Lestosaurus* and *Tylosaurus*, there is apparently another pair of hyoid bones, more slender than the one here figured.

The Sclerotic Plates.

In the genera *Lestosaurus* and *Tylosaurus*, the orbit was protected by a ring of osseous plates, somewhat like those in *Ichthyosaurus*, and a few recent birds. This ring was composed of only a single row of plates, which in position overlapped each other. These plates are subrectangular in shape, longer than wide, and their general features are shown in the figures given below. The lateral edges are bevelled so as to form a strong union. This bevelling is not uniform, but is so situated as to produce three kinds of plates. Some of these are shaped like those in several modern birds, where the opposite lateral edges are bevelled, one above and the other below (figure 2*a*), forming when united a regular imbricated ring. Besides this variety, however, two other kinds are found in Mosasauroids, namely: one with both lateral edges bevelled below (figure 3), and the other with these margins bevelled above (figure 4). These three kinds occur in the same orbit. All of these plates are somewhat curved, with the concavity external. The outer margins are thickened, and the inner thin and sharp. The

subrectangular shape of all the plates shows that when in position, the outer and inner diameters of the sclerotic ring were not widely different.



Figures 2, 3, and 4.—Sclerotic plates of *Lestosaurus simus*, Marsh; natural size, external view.

The sclerotic plates of the Mosasauroids may be distinguished from the dermal scutes on the head and body by their peculiar shape, and much larger size. The latter, so far as known, are more rhombic in form, but their variations on different parts of the body, and in different species, remain to be determined.

The Transverse Bone.

The element in the reptilian skull which Cuvier called the transverse bone, and Owen, the ectopterygoid, has not been observed hitherto in the Mosasauroids, but it is present in *Tylosaurus*, *Lestosaurus*, and *Edestosaurus*. In the first of these genera, it is an L-shaped bone, thin and somewhat twisted. One ramus unites by suture with the corresponding process of the pterygoid, and the other extends forward, nearly at a right angle, to join the posterior end of the maxillary.

The Pterygoid Bones.

There has been some uncertainty in regard to the bones called pterygoids by Cuvier, but the accuracy of his determination can no longer be fairly questioned. Various specimens in the Yale Museum show conclusively that the dentigerous bones of the palate in various genera of Mosasauroids were attached posteriorly to the quadrates by ligament; to the basipterygoid processes in the same way; to the maxillaries by the intervention of a distinct transverse bone; and to the true palatines by squamous suture. Cope has called these dentigerous bones "*palatines*," and stated that they were separated from the quadrates by intervening bones;* but on both points he was in error. The true palatines are small edentulous bones, in front and outside of the pterygoids. They

* Vertebrata of the Cretaceous, p. 118.

separate the latter from the slender, distinct vomers. In the genus *Tylosaurus*, the posterior ends of the pterygoids form a distinct head. In *Lestosaurus* and *Holosaurus*, this extremity is broad and thin. In none of these genera were the pterygoids united by suture on the median line, but were more or less widely separated.

The new characters above presented are all Lacertilian, rather than Ophidian. The important characters of the Mosasauroids now known indicate that they form a suborder of the Lacertilia, which should be called *Mosasauria.*

Holosaurus abruptus, gen. et sp. nov.

The type specimen on which the present genus is based is one of the most complete skeletons of the Mosasauroid reptiles yet discovered. This genus is most nearly related to *Lestosaurus*, and agrees with it in the form and general characters of the skull. It may be readily distinguished by the coracoid, which is entirely without emarginations, as well as by other points of difference. From *Tylosaurus* it is separated widely by the premaxillaries, mandibles, and the palatines.

The present species was one of the shortest in proportion to its bulk hitherto described, the skull and tail being both abruptly terminated. The entire length was about twenty feet. There are 98 vertebræ preserved between the skull and a point in the tail where the caudals have a diameter of one inch. Many of these vertebræ are in position. The caudals preserved all had articulated chevrons.

Some of the dimensions of the present specimen are as follows:

Length of entire lower jaw (two feet)	610·mm
Length of dentary bone, on lower border	342·
Length of twelfth vertebra	71·
Transverse diameter of ball	50·
Length of twentieth vertebra	85·
Length of humerus	146·
Width of distal end	136·
Length of radius	102·
Length of ulna	88·
Length of femur	141·
Width of distal end	85·
Length of fibula	117·
Width of distal end	100·
Length of tibia	99·
Width of distal end	76·

This specimen was found in the yellow Cretaceous chalk of Kansas, by Mr. S. W. Williston, of the Yale Museum.

Yale College, New Haven, Dec. 20th, 1879.

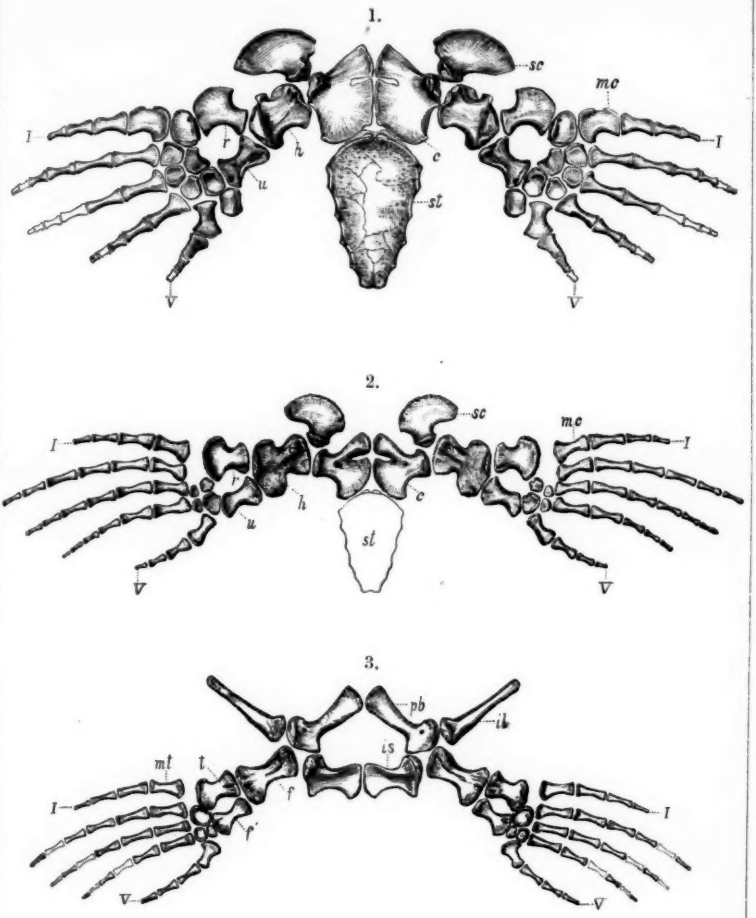


Figure 1.—Scapular arch, sternum, and fore limbs of *Edestosaurus dispar*, Marsh; seen from above, one-fifth natural size; *sc.* scapula; *c.* coracoid; *st.* sternum; *h.* humerus; *r.* radius; *u.* ulna; *mc.* metacarpal; *I.* first digit; *V.* fifth digit.

Figure 2.—Scapular arch and fore limbs of *Lestosaurus simus*, Marsh; seen from below, one-sixteenth natural size. Letters as in figure 1. Outline of sternum from *Edestosaurus*.

Figure 3.—Pelvic arch and hind limbs of *Lestosaurus simus;* seen from below, one twelfth natural size; *il.* ilium; *pb.* pubis; *is.* ischium; *f.* femur; *t.* tibia; *f'.* fibula; *mt.* metatarsal.

The paddles are represented as horizontal, and the bones of the arches are somewhat displaced to bring them into the same plane.